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A STUDY OF LAKE ONTARIO — ST. LAWRENCE RIVER SMALLMOUTH BASS

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ABSTRACT

A study of smallmouth bass of the eastern Lake Ontario-Thousand Islands region was carried on during 1944-50. Tagging of 4,408 wild, adult bass at 10 principal localities was undertaken to determine if populations were homogeneous. Studies of age, growth and reproduction of the bass from different localities were made. Metal strap tags used on the dorsal fin and maxillary during 1944-45 gave recoveries of only 2.0 per cent and 9.1 per cent, respectively. During 1946-50 round, metal strap tags, applied to the lower jaw, were used on a total of 2,853 fish. This method gave 612 recoveries (21.5 per cent). Angling recoveries were used as an index to the catch of bass on various grounds during different months of the fishing season. Despite a relatively heavy take of bass on some grounds during June there was no evidence that the early fishing affected the population adversely. Heaviest returns, generally, were in August. Distinct populations of bass were recognized using migrations and growth as the main criteria for separation. Four to 6 years are required in this area for bass to reach the legal length of 10 inches. The oldest bass found were 14 years old. Considerable variation in spawning time was found to be a characteristic of bass in this region. Late May to early June spawning occurred in tributary streams and in some of the warmer bays while late June-July spawning occurred among the fish influenced by the cold water of Lake Ontario.

Fishing grounds of the eastern Lake Ontario-Thousand Islands region are the largest and probably most productive for smallmouth bass in the State. A long-term study of the bass in this region was begun in 1944. Tagging of wild, adult bass was undertaken in order to determine the nature and extent of their movements and to find out if populations are homogeneous or possibly need management of a local, specific type. Studies of age and growth of the bass obtained from different localities were made and the natural reproduction of bass in the region was investigated. In addition, consideration was given to certain specific problems such as the effect of

the June fishing on the maintenance of the bass fishing on the different grounds.

PROCEDURE

During the years 1944-1950, bass totaling 4,408 were tagged. These fish were obtained by means of small trap nets operated in depths of 5 to 20 feet of water. The majority of the fish were netted during the first two weeks of June although in 1945-46 some bass were tagged during the last week of May. The general area where tagging was done extends from Henderson Bay to and down the St. Lawrence River as far as Eel Bay (Figure 1). Tagging was carried on at the following localities on the St. Lawrence River: the foot of Eel Bay, Linda Island, Dodge Bay, Sunnybank, and the head of Carleton Island. In Lake Ontario the principal localities were: Wilson Bay, East Charity Shoal, North Shoal off Galloo Island, and the foot of Stony Island. The Chaumont Bay bass were tagged at Three Mile Bay and off Point Peninsula.

All bass were tagged and released at the locality of capture with the exception of 313 specimens which were tagged on July 20, 1944 after being used as breeders by the Federal hatchery at Cape Vincent. Records for the hatchery-held fish are used in this study only in the calculation of the percentages of recovery according to the method of tagging.

Various data were recorded for fish to be tagged, as well as for tagged fish when recaptured. All measurements of the fish were made in total length. Since some of the specimens were obtained during the early part of the spawning period it was possible to secure data as to their sex. Many of the males were ripe. While relatively few females were ripe, the enlarged abdomen and appearance of the vent made sex recognition possible. Scales for the study of age and growth were taken from all fish at the time of tagging and again if they were recaptured in project netting during subsequent years. Age was determined by counting the number of annuli (winter marks) on the scales. On the basis of scale examinations the last annulus was considered to be marginal on all scales obtained during the tagging work, January 1 being taken as the transition date into the next age group.

The tagging program was given considerable publicity and help in obtaining returns by local newspapers, fish and game clubs, guides, resort owners, commercial fishermen, Department game protectors, the Federal hatchery at Cape Vincent, the Department of Fisheries

of the Province of Ontario, Queens University, fish and game clubs in Kingston (Ontario), and many interested sportsmen.

FINDINGS

The fact that an appreciable amount of the bass fishing by non-resident anglers is done with the aid of guides in this territory helped considerably in obtaining reports of the tagged fish caught by this group. It is known that some of the tags taken by anglers were not reported but it is believed that at least 50 per cent of the tagged fish caught were reported and probably the return was much higher in some localities.

METHODS OF TAGGING AND PERCENTAGES OF RECAPTURE

A relatively small amount of information was available at the time this study was begun as to the most successful methods of tagging bass. Snyder (1932) marked bass with aluminum tags fastened to the upper portion of the gill cover. He released 150 tagged bass in Lake Ontario near Cape Vincent in early July 1931 and reported a recovery of 19 fish (12.7 per cent) by angling during the summer of 1931 and the forepart of the following fishing season. However, he mentioned that the tags had practically worn through the gill covers of the fish caught the second season.

During the early years of this study experiments were carried on with metal strap tags (Salt Lake, size 3) applied to the dorsal fin and also around the maxillary bone. In the year 1944 a total of 587 fish received tags on the front of the second dorsal fin. From this group only 12 recoveries (2.0 per cent) were made during the year of tagging and none has been reported in subsequent years. The maxillary method was used on 1,039 fish during the years 1944-1946. This tagged stock gave an angling return of 9.1 per cent, the bulk of the tags (94.7 per cent) being recovered during the year of tagging while the second and third fishing seasons yielded 4.2 and 1.1 per cent of the returns, respectively. An additional 2.8 per cent of the maxillary tags were recovered in project netting. It was observed during the netting operations of June 1946 and 1947 that 38 bass had obviously lost their maxillary tags. The tag had finally worn through the maxillary bone. It should be mentioned that the actual number of fish tagged by the dorsal and maxillary methods was 71 fish less than the total of 1,626 reported above due to the fact that 71 fish received tags on both the dorsal fin and maxillary.

In view of the poor results with the dorsal and maxillary tags

TABLE 1. RECOVERY BY ANGLING OF BASS TAGGED ON LOWER JAW ACCORDING TO LOCALITY AND YEAR OF TAGGING*

Locality	Year tagged	Number tagged	Recoveries		Number of recoveries in various fishing seasons after tagging§					
			Number	Per cent	1st	2nd	3rd	4th	5th	6th
East Charity Shoal	1949	416	55	13.2						
	1950	169	24	14.2						
Sub-total		585	79	13.5	30	20	26	3	..	..
North Shoal	1950	189	37	19.6	20	12	5	..	..	..
Stony Island	1950	111	32	28.8	17	14	1	..	..	..
Six Town Point	1950	18	8	44.4	5	..	3	..	..	..
Wilson Bay	1946	60	11	18.3						
	1947	513	98	19.1						
	1948	58	15	25.9						
Sub-total		631	124	19.7	69	25	18	6	5	1
Eel Bay	1948	399	98	24.6						
	1949	194	41	21.1						
Sub-total		593	139	23.4	92	29	8	7	3	..
Linda Island	1946	101	24	23.8						
	1947	140	45	32.1						
	1948	40	6	15.0						
Sub-total		281	75	26.7	30	24	16	5	..	..
Dodge Bay	1946	98	31	31.6						
	1947	133	31	23.3						
	1948	40	9	22.5						
Sub-total		271	71	26.2	32	25	8	5	1	..
Carleton Island	1946	11	3	27.3						
	1947	82	24	29.3						
Sub-total		93	27	29.0	8	12	4	1	2	..
Sunnybank	1946	5	2	40.0						
	1947	76	18	23.7						
Sub-total		81	20	24.7	14	4	2	..	..	..
Total		2,853	612	21.5	317	165	91	27	11	1

* Includes recoveries through 1952 season.

§ Only total figures given for each locality because of relatively low numbers involved.

a round metal strap tag (Salt Lake, length straightened 2¼ inches) was tried on the lower jaw, beginning during the 1946 season. Good results were obtained with this tag without appreciable harm to the jaw bone of the fish and thus the method was continued for the remainder of the study.

The lower jaw method was used on a total of 2,853 fish. By the end of the year 1952 this group had given an angling return of 612 tags (21.5 per cent). Percentages of the total number of returns according to recovery in subsequent fishing seasons were in the following order: first (year of tagging), 51.8 per cent; second, 26.9 per cent; third, 14.9 per cent; fourth, 4.4 per cent; fifth, 1.8 per cent, and sixth, 0.2 per cent. Netting operations gave 107 additional returns (3.8 per cent). The percentages of recovery of the jaw tagged bass according to locality and year of tagging are given in Table 1.

Since all bass were tagged prior to June 16, the opening date for bass fishing in the area, the fish were subjected to a complete season of fishing during each year of tagging. Some localities gave a rather high percentage of recovery considering the small numbers of fish tagged there. This may indicate a high fishing intensity on relatively small local groups of bass. On the other hand, at Charity Shoals which is known to have a heavy fishing pressure, the percentages of recovery were the lowest for the whole region. This may show that the bass population at Charity was large or it may be that appreciable numbers of the tagged fish were lost to natural mortality. Most of the bass tagged at Charity were in the older age groups (Table 3).

The angling recaptures of tagged bass according to month taken for the different tagging localities are summarized in Table 2. The returns are expressed in percentages of the total number of recoveries for each locality. It is believed that these returns serve as an index to the catch of bass on various grounds during June as well as in other months of the fishing season. Heaviest returns in June were from fish tagged at East Charity Shoal. The bulk of these returns came from the locality of tagging. An appreciable number of the fish tagged at Eel Bay were also taken in June (30.8 per cent of the recaptures). Most of these fish were caught in Eel Bay. Lowest June returns were from fish tagged at Stony Island and for the St. Lawrence River localities between Carleton and Linda Islands. August returns were high for all localities except North Shoal and East Charity Shoal.

Table 2. Recovery By Angling of All Tagged Bass According to Month Taken and Locality of Tagging (1944–52)*

Locality	Total recoveries§	June 16–30	July 1–15	July 16–31	Aug. 1–31	Sept. 1–30	Oct. 1–31	Nov. 1–30
East Charity Shoal	78 (1)	61.5	2.5	9.0	16.7	9.0	...	1.3
North Shoal	37	24.3	27.0	5.4	18.9	18.9	5.4	...
Stony Island	32	6.2	18.8	18.8	37.5	15.6	...	3.1
Six Town Point	7 (1)	...	...	...	71.4	28.6	...	...
Wilson Bay	166 (21)	10.8	10.8	16.3	47.6	13.9	0.6	...
St. Lawrence River (Sunnybank, Dodge Bay, Carleton and Linda Islands)	166 (39)	9.0	16.9	15.1	43.9	14.5	0.6	...
Eel Bay	130 (9)	30.8	6.2	8.5	40.0	11.5	3.0	...
Chaumont Bay (Three Mile Bay, Point Peninsula)	17 (2)	11.8	11.8	5.8	41.2	29.4	...	...
Total	633 (73)	21.2	11.7	12.5	39.2	13.9	1.2	0.3

* Expressed as percentages of the total number of recoveries for each locality.
§ Additional recoveries not used here due to undetermined dates taken are shown in parentheses.

Bass Migrations

Movements of the bass tagged at East Charity Shoal, based upon 79 recaptures, are shown in Figure 1. Sixty fish were caught within a 1-mile radius of the point of release. Movements to shoals or island areas in the open lake (Duck Islands, Amherst Island, False Duck Islands, Grenadier Island, Allan Otty Shoal, and Big Bar Shoal) were made by 13 fish. Migrations to bays at the head of Wolfe Island were made by three individuals. Only two of the Charity tagged fish were reported caught from the St. Lawrence River, one at the head of Howe Island and the other between Fisher's Landing and Round Island. It is doubtful if the Charity bass leave the open lake and move into the river in sufficient numbers to contribute to the fishing there. The longest migration that was recorded was made by a Charity bass which was recaptured at the black buoy at the entrance to Sodus Bay which is located on the south shore of Lake Ontario in Wayne County. It is possible that this migration was influenced by strong currents in the lake during storms.

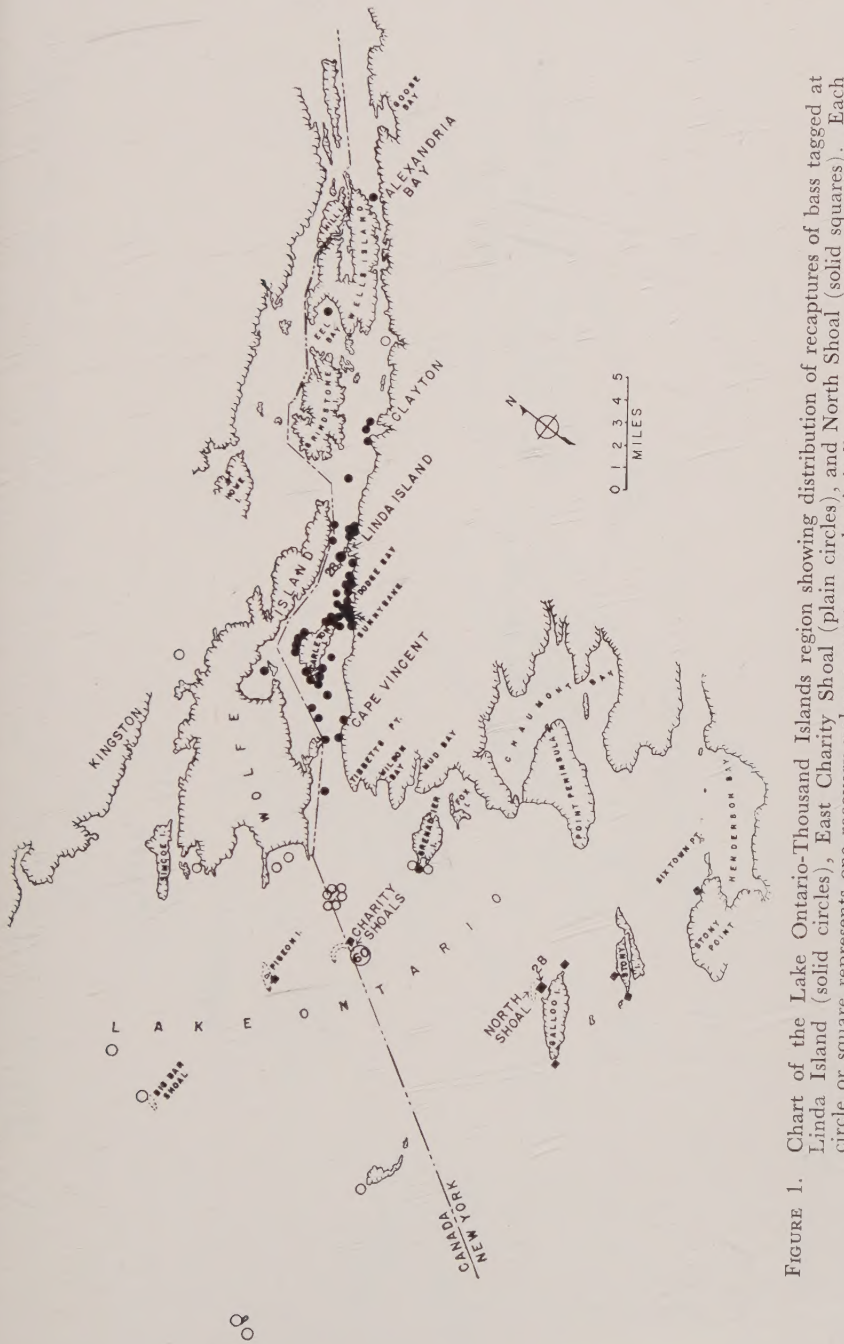

FIGURE 1. Chart of the Lake Ontario-Thousand Islands region showing distribution of recaptures of bass tagged at Linda Island (solid circles), East Charity Shoal (plain circles), and North Shoal (solid squares). Each circle or square represents one recovery unless a greater number is indicated.

Figure 2. Distribution of recaptures of bass tagged at Dodge Bay (solid circles), foot of Stony Island (plain circles), and Six Town Point (solid squares). Each circle or square represents one recovery unless a greater number is indicated.

FIGURE 3. Distribution of recaptures of bass tagged at Three Mile Bay (solid circles) and Wilson Bay (plain circles). Each circle represents one recovery unless a greater number is indicated.

Of the bass tagged at the North Shoal off Galloo Island, 32 recaptures were made within the Galloo-Stony Island area (Figure 1). One fish traveled to Pigeon Island, another was recorded off Stony Point, and a third was caught at East Charity Shoal. The locality of recapture was not determined for two returns.

The distribution of recaptures of bass tagged at the foot of Stony Island is shown in Figure 2. A total of 23 returns came from the Galloo-Stony Island area. One fish moved into the St. Lawrence River and was caught in Eel Bay. Movement to inshore areas was as follows: vicinity of Point Peninsula, three fish; Association Island, two fish; Stony Point, one fish; Lime Barrel Shoal, one fish. For one individual, the locality of recapture was undetermined.

A small number of bass were tagged off Six Town Point which lies at the entrance to Henderson Bay. Seven returns showed movements within the Henderson Bay region while one fish traveled to the foot of Stony Island (Figure 2).

For bass tagged by the dorsal and maxillary methods at Three Mile Bay the 11 returns are shown in Figure 3. Although all of these recoveries were made within Chaumont Bay the general trend of their movements was toward Lake Ontario. It is believed that bass do move into Chaumont Bay from the open lake at spawning time.

During the period 1944-1952 migration data from 173 recaptures of bass tagged at Wilson Bay were obtained. This return includes maxillary tagged fish as well as the jaw tagged individuals on which data are given in Table 1. An additional 14 returns were not usable here because they lacked the locality of recapture. About 35 per cent of the recaptures of the Wilson Bay fish were made less than 1 mile from the foot of the bay where the tagging was done, while an additional 29 per cent represents recaptures in the St. Lawrence River (Figure 3). It appears that the Wilson Bay fish contribute more to the fishing in the river than any of the other groups of bass which were tagged at localities in or adjoining Lake Ontario. While the majority of the bass were taken at distances less than 5 miles down the river, one fish was reported at Alexandria Bay—a migration of about 30 miles. A southward migration to the vicinity of Mud Bay, Fox and Grenadier Islands was shown by about 25 per cent of the recaptures. It is possible that the run of fairly large bass that appears at times on the shoals at the head of Grenadier Island during early July is from the Wilson Bay population. The remaining 11 per cent represented fish which had moved across the international boundary

FIGURE 4. Chart of St. Lawrence River showing distribution of recaptures of bass tagged at Eel Bay (solid circles) and Carleton Island (plain circles). Each circle represents one recovery unless a greater number is indicated.

to the head of Wolfe Island as well as migrations to the Duck Islands and the Galloo-Stony Island area.

Of the 81 recaptures of bass tagged at Linda Island by the maxillary and lower jaw methods, migration data were obtained on 76 fish (Figure 1). Local movements (less than 1 mile) were made by 28 fish, while 11 fish moved downriver and 37 individuals traveled upriver toward Lake Ontario. Of the downriver migrants five traveled distances of 5 miles or more but none was recorded below Eel Bay. While 17 of the upriver migrants traveled 5 miles or more, only one fish was taken in Lake Ontario.

Both the maxillary and lower jaw methods were used on the bass tagged at the southwest tip of Carleton Island. This group gave 33 recoveries including two for which the locality of recapture was not reported. Figure 4 shows the distribution of 30 returns. Local movements around the island were exhibited by most of these fish. Only three individuals traveled distances of 5 miles or more including one fish (not shown on Figure 4) which was taken in Lake Ontario at the head of Grenadier Island.

A total of 71 recaptures of bass tagged at Dodge Bay has been reported. Figure 2 shows the distribution of these returns except for 11 that lacked information on the locality of recapture. It appears that the fish tagged at Dodge Bay were mostly on the move, probably to spawning areas. Recoveries of 47 fish showed movements toward Lake Ontario, while 11 individuals traveled downriver. Only two fish were recovered near the point of release. Returns on the fish tagged off Sunnybank showed movements similar to those from the Dodge Bay locality.

The migration data indicate a local population of bass in the region of Eel Bay although there is apparently some intermingling with bass from other areas, particularly during the spawning season. About 50 per cent of the recaptures of fish tagged at Eel Bay were taken within Eel Bay (Figure 4). Only 10 fish traveled downriver appreciable distances, the farthest being to Chippewa Bay. Movements upriver to areas beyond the head of Grindstone Island were shown by 12 fish. Longest upriver movements were to Horne's Dock (opposite Cape Vincent) and to Kingston, Ontario.

Growth

Growth data based on samples from the spawning runs at Charity Shoals, Wilson Bay, and Eel Bay are given in Tables 3 to 5 and Figure 5. Data from these localities are given in detail because of

TABLE 3. AGE-LENGTH RELATIONSHIP ACCORDING TO SEX AND AGE OF 201 BASS FROM COMBINED SAMPLES COLLECTED AT EAST CHARITY SHOAL IN 1949 AND 1950

Length in inches	Age group and sex																								
	IV		V		VI		VII		VIII		IX		X		XI		XII		XIII		XIV		Total		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Both sexes
10.0 to 10.9	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1
11.0 to 11.9	..	..	..	..	2	1	1	..	..	..	..	..	..	1	1	..	1	..	..	..	..	..	5	2	7
12.0 to 12.9	..	..	..	..	..	..	..	..	..	..	..	..	1	..	7	7	1	..	1	..	..	..	10	7	17
13.0 to 13.9	..	..	..	..	..	..	..	..	..	..	..	2	3	..	15	26	6	8	..	..	..	..	24	36	60
14.0 to 14.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	17	16	17	24	1	1	..	..	35	41	76
15.0 to 15.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	4	11	13	1	1	..	1	17	19	36
16.0 to 16.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	2	..	..	1	3	4
Total specimens	1	..	..	..	2	1	1	..	..	..	..	2	4	1	45	53	37	46	3	4	..	1	93	108	201
Average length Each sex	10.5	..	..	..	11.6	11.8	11.6	..	..	..	..	13.1	13.2	11.9	13.8	13.7	14.4	14.6	14.2	15.6	..	15.6	13.9	14.2	XXX
Sexes combined	10.5		..		11.6		11.6		..		13.1		13.0		13.7		14.5		15.0		15.6		14.1		
Per cent male	100		..		67		100		..		0		80		46		45		43		0		46		

Table 4. Age-length Relationship According to Sex and Age of 520 Bass from Combined Samples Collected at Wilson Bay in 1947 and 1948

Length in inches	Age group and sex																					
	IV		V		VI		VII		VIII		IX		X		XI		XII		XIII		Total		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Both sexes
10.0 to 10.9	2	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	4
11.0 to 11.9	3	..	7	..	11	2	..	1	2	2	1	1	..	..	..	..	..	..	..	..	24	6	30
12.0 to 12.9	5	..	9	2	30	2	7	5	11	3	5	5	..	..	..	..	..	..	..	..	67	17	84
13.0 to 13.9	..	..	2	..	18	5	16	5	22	24	24	19	1	..	..	..	..	..	..	..	83	53	136
14.0 to 14.9	..	..	..	..	3	..	3	6	34	17	40	38	5	8	..	..	..	..	..	..	85	69	154
15.0 to 15.9	..	..	..	..	..	1	5	2	11	4	21	16	5	9	..	2	..	..	..	..	42	34	76
16.0 to 16.9	..	..	..	..	..	..	..	..	3	2	4	5	5	5	1	1	1	..	..	1	14	14	28
17.0 to 17.9	..	..	..	..	..	..	1	..	..	1	..	..	3	1	..	1	..	1	..	..	4	4	8
Total specimens	10	..	20	2	62	10	32	19	83	53	95	84	19	23	1	4	1	1	..	1	323	197	520
Average length Each sex	11.7	..	11.9	12.4	12.6	13 0	13.7	13.7	14.0	14.1	14.3	14 4	15.7	15 3	16.3	16.1	16.8	17.0	..	16.6	13.7	14.2	XXX
Sexes combined	11.7		11.9		12.7		13.7		14.0		14.4		15.5		16.1		16.9		16.6		13.9		
Per cent male	100		91		86		63		61		53		45		20		50		0		62		

TABLE 3. AGE-LENGTH RELATIONSHIP ACCORDING TO SEX AND AGE OF 331 BASS FROM SAMPLE COLLECTED AT EEL BAY IN 1948

Length in inches	Age group and sex																						
	V		VI		VII		VIII		IX		X		XI		XII		XIII		XIV		Total		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Both sexes
9.0 to 9.9	4	..	9	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	15	..	15
10.0 to 10.9	7	..	29	1	15	2	3	..	..	..	..	..	..	..	..	..	..	..	..	..	54	3	57
11.0 to 11.9	4	..	19	2	36	10	11	1	2	..	..	..	..	..	..	..	..	..	..	..	72	13	85
12.0 to 12.9	..	..	6	8	20	10	13	3	3	3	..	..	..	..	..	..	..	..	..	..	42	24	66
13.0 to 13.9	..	..	1	..	7	3	4	1	4	4	..	1	..	..	..	..	..	..	..	..	16	9	25
14.0 to 14.9	..	..	1	..	1	..	5	1	..	6	2	3	..	..	..	..	..	..	..	..	9	10	19
15.0 to 15.9	..	..	..	..	..	..	..	3	4	3	1	3	..	1	..	..	..	..	..	..	5	10	15
16.0 to 16.9	..	..	..	..	..	..	..	2	3	3	..	6	1	3	..	..	..	..	..	..	4	14	18
17.0 to 17.9	..	..	..	..	..	..	..	..	2	2	..	2	3	5	4	2	..	..	..	..	9	11	20
18.0 to 18.9	..	..	..	..	..	..	..	..	..	..	1	..	1	2	..	3	..	2	..	..	2	7	9
19.0 to 19.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	2	2
Total specimens	15	..	65	11	81	25	36	11	18	21	4	15	5	11	4	6	..	2	..	1	228	103	331
Average length Each sex	10.3	..	10.9	11.9	11.7	12.1	12.4	14.2	14.4	14.7	15.7	15.8	17.2	17.1	17.4	18.0	..	18.6	..	19.0	12.0	14.4	XXX
Sexes combined	10.3		11.0		11.8		12.8		14.6		15.8		17.1		17.8		18.6		19.0		12.7		
Per cent male	100		86		76		77		46		21		31		40		0		0		68		

the large number of fish taken in the samples and because the samples are considered to be representative of different types of habitat. Charity Shoals is located in the open lake, Wilson Bay is inshore on the lake, and Eel Bay is well down the river.

The growth curves in Figure 5 indicate that separate and distinct populations of bass may exist in these localities, each having its own

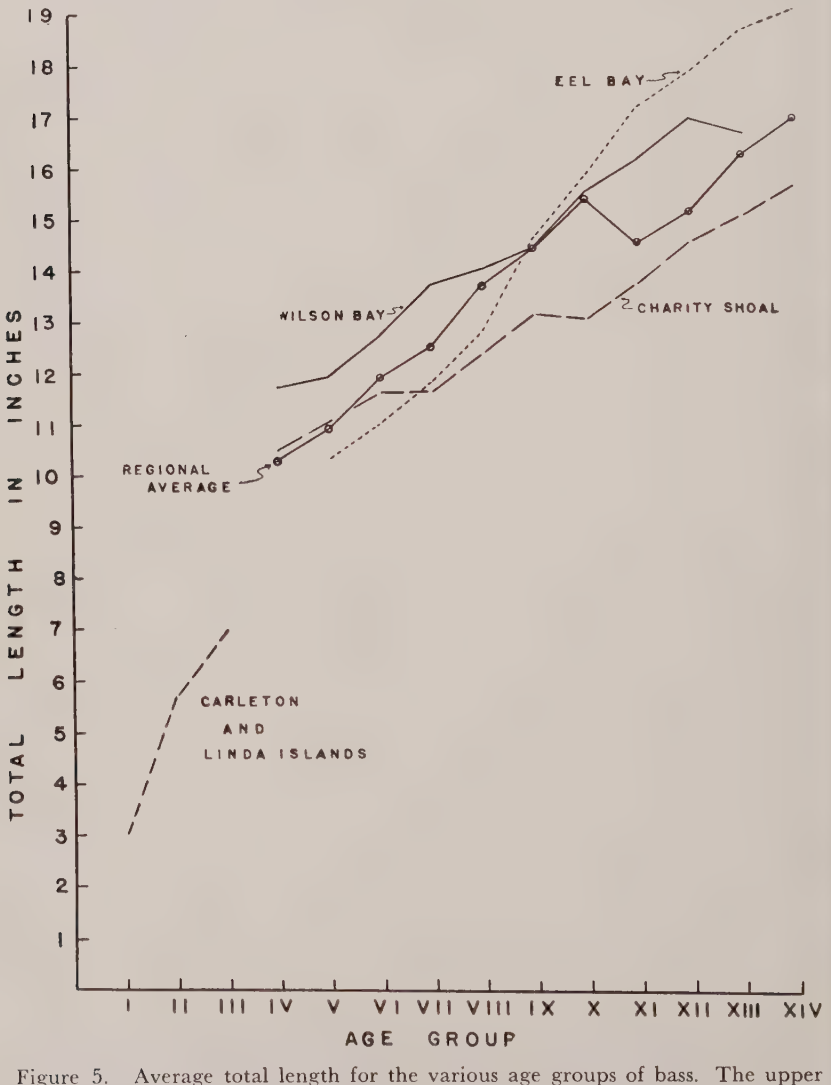

Figure 5. Average total length for the various age groups of bass. The upper four curves are based on Table 7. The lower curve for young bass is based on data from immature specimens taken by angling.

growth-rate characteristics. The slower growth of the Charity Shoals bass may be due to the cooler water temperatures which prevail in the open lake, a less abundant food supply than inshore, or a combination of these conditions. Eel Bay has a reputation for producing many small bass. It also has an abundance of other species of small size such as yellow perch, rock bass and sunfish, all of which may result in such severe competition for the types of food utilized by the small bass that the early growth of the bass is retarded. However, the Eel Bay bass eventually catch up and surpass in size bass of the same age in the other two localities. In general, the older bass of the open lake do not attain the size reached by inshore and river bass of the same age.

On the average, it requires 4 to 6 years in the region under study for a bass to reach the legal length of 10 inches. This growth rate is considerably slower than that found in many inland waters in New York State, particularly further south where the growing season is longer. Also, the general abundance of rock bass and yellow perch probably further reduces the growth of the small bass through competition for food. In reading the scales it was noted that the second and third annuli often occurred very close together, indicating unusually poor growth in the third year of life, a period when the bass were at a size at which they might be expected to suffer most from competition with the rock bass and perch. Greeley (1940) says "The relatively poor growth of juvenile bass is explainable by assuming intense competition conditions. Observations indicate that these fish are often found in conditions of heavy fish population. One area, the 'gas buoy' shoals off Galloo Island, had small bass so abundant in late July that they might very well have been expected to limit each other's food supply. Many other grounds, particularly shore areas, have relatively fewer small bass but have an abundance of rock bass, sunfish, perch and other fish which compete with small bass."

There was little difference in rate of growth between the sexes. Table 6 demonstrates this particularly well for a sample of bass of age group IV. In the Eel Bay samples (Table 5) it appears that the females in the younger age groups averaged slightly greater in length than the males, but this was possibly due to the larger females of these age groups maturing and entering the spawning runs first.

Both sexes have been combined in Table 7 which gives a comparison of the growth rates found in the various localities where netting was done. The data on the Chaumont Bay bass indicate that in general the bass in this area grow somewhat faster than those in the other areas sampled. This may be due to the removal of competitive

Table 6. Length-frequency Distribution of Smallmouth Bass of Age Group IV, According to Sex, Taken in Gill Nets Set Northeast of Stony Island on August 19-20, 1943

Length in millimeters	Number male	Number female	Sexes combined
220—229	2	...	2
230—239	1	1	2
240—249	1	4	5
250—259	4	6	10
260—269	7	9	16
270—279	6	8	14
280—289	5	2	7
290—299	2	2	4
300—309	1	1	2
Average length In millimeters	268	267	267
In inches	10.6	10.5	10.5
Number specimens	29	33	62

fish by the commercial fishery which operates in the Chaumont Bay area. The samples obtained from the off-shore areas in Lake Ontario showed that the Stony Island fish grew faster than the North Shoal and Charity Shoal bass. Rates of growth of the bass from Wilson Bay, Carleton Island, Sunnybank, and Dodge Bay were similar.

Sex Ratio

In the samples taken from the spawning runs there was a tendency for males to be distinctly predominant among the younger fish and for females to be slightly predominant among the older fish, while the sexes were about equally represented among the fish of intermediate age and size. Tables 4 and 5 illustrate this general tendency. Several factors may have influenced the sex ratio in the samples. Among these are: (1) the original sex ratio at hatching; (2) the age at which each sex matures; (3) differential rate of mortality due to natural causes.

No data were obtained in this study as to the sex ratio at time of hatching, which is believed to be 50-50. However, information was

TABLE 7. COMPARISON OF THE AVERAGE TOTAL LENGTH (INCHES) OF BASS FROM DIFFERENT LOCALITIES IN THE LAKE ONTARIO-ST. LAWRENCE RIVER REGION ACCORDING TO AGE (SEXES COMBINED)*

Locality	Year	Age group										
		IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
East Charity Shoal	1949 50	10.5 (1)	.....	11.6 (3)	11.6 (1)	.....	13 1 (2)	13.0 (5)	13.7 (98)	14.5 (83)	15.0 (7)	15.6 (1)
North Shoal.....	1950	10.0 (1)	.....	11.7 (11)	12.4 (11)	12.9 (8)	13.2 (6)	14.2 (11)	14.5 (49)	15.1 (72)	16.0 (9)	16.3 (1)
Stony Island.....	1950	10.2 (9)	11.2 (7)	11.8 (29)	12.5 (22)	13.4 (11)	12.9 (3)	15.1 (2)	15.1 (8)	15.6 (8)	16.9 (1)	.....
Wilson Bay.....	1947 48	11.7 (10)	11.9 (22)	12.7 (72)	13.7 (51)	14.0 (136)	14.4 (179)	15.5 (42)	16.1 (5)	16.9 (2)	16.6 (1)	.....
Carleton Island...	1947	9.7 (7)	11.0 (18)	12.1 (13)	12.4 (3)	13.8 (18)	14.7 (19)	16.9 (1)	16.6 (1)	.. .	18.1 (2)	.....
Sunnybank.....	1947	9.6 (1)	11.3 (21)	12.2 (15)	13.1 (6)	14.3 (19)	15.3 (7)	.....	.....	.. ..	.....	.....
Dodge Bay.....	1947-48	10.4 (10)	10.7 (39)	11.9 (46)	13.2 (32)	13.6 (23)	14.8 (19)	15.7 (5)	.. ..	....	.....	.....
Linda Island.....	1947-48	8.1 (6)	9.9 (21)	11.3 (26)	12.0 (22)	13.2 (34)	14.4 (19)	15.8 (15)	16.8 (5)	17.5 (3)	.....	.....
Eel Bay.....	1948	....	10.3 (15)	11.0 (76)	11.8 (106)	12.8 (47)	14.6 (39)	15.8 (19)	17.1 (16)	17.8 (10)	18.6 (2)	19.0 (1)
Chaumont Bay...	1945	11.1 (4)	11.8 (9)	13.4 (30)	14.3 (3)	15.6 (12)	16.5 (3)	16.6 (2)	17.8 (1)	.....	.....	.....
All localities.....	.....	10.3 (49)	10.9 (152)	11.9 (321)	12.5 (257)	13.7 (308)	14.4 (296)	15.4 (102)	14.5 (183)	15.1 (178)	16.2 (22)	16.9 (3)

* The number of specimens upon which each average is based is shown in parentheses.

obtained on a group of relatively young bass which were taken on August 19-20, 1943 in 60 to 80 feet of water by means of gill nets ranging in mesh size from 1½ to 5 inches. The nets were set in an area northwest of Bass Island and northeast of Stony Island, a locality which is roughly 12 miles south of Wilson Bay. The composition of the catch is shown in Table 8. These data have been presented because the sample was taken late enough in the summer so that the sex ratio should not have been influenced by spawning behavior and because there was little or no selectivity due to gear. Both mature and immature specimens of each sex occurred in this sample, and, although the number of fish taken was small, it seems reasonable to assume that the sample was representative of age group IV, at least. It appears that the two sexes occurred in about equal numbers when in their fifth year of life.

Table 8. Number of Smallmouth Bass, According to Age and Sex, Taken in Gill Nets Set Northeast of Stony Island on August 19-20, 1943

Age group	Number			Per cent	
	Male	Female	Total	Male	Female
III	1	2	3	33	67
IV	29	33	62	47	53
V	10	7	17	59	41
Total	40	42	82	49	51

The second factor, the age at which each sex matures, is important in explaining the high percentage of males among the younger fish. The male bass mature at an earlier age than the females. Since the spawning run consists primarily of mature fish, these younger males enter the run while females of the same age which have not matured are normally absent from the run. As the females mature they in turn enter the run. If the original sex ratio of young bass was 50-50, then this ratio again should be reached in the spawning run when all the fish have matured. In both the Wilson Bay and Eel Bay samples the 50-50 ratio was reached when the fish were about 8 or 9 years old.

The third factor, differential rate of mortality due to natural causes, probably has an influence on the sex ratio found among older

bass. The presence of an increasing percentage of females as a given age class becomes older has been noted by other workers. Hile (1941) concluded that the inherent viability of the male fish was less than that of the female and was the cause of such an increasing relative abundance of females among the rock bass of Nebish Lake in Wisconsin. The fact that male smallmouth bass mature about 2 years earlier than the females should be considered as a factor tending to shorten the average life span of the male bass.

Table 9. Number and Percentage of Bass, According to Sex, Taken At Various Localities (1946-50)

Locality	Number			Per cent	
	Male	Female	Total	Male	Female
East Charity Shoal	272	328	600	45	55
North Shoal	67	106	173	39	61
Stony Island	58	59	117	50	50
Wilson Bay	424	277	701	60	40
Six Town Point	5	13	18	28	72
Three Mile Bay	18	15	33	55	45
Carleton Island	51	34	85	60	40
Sunnybank	47	24	71	66	34
Dodge Bay	106	70	176	60	40
Linda Island	144	109	253	57	43
Eel Bay	313	184	497	63	37
Total	1,505	1,219	2,724	55	45

The numbers and percentages of males and females taken in various localities are given in Table 9. The overall predominance of males in the samples is due to the generally greater abundance of bass of the younger age groups. In the exceptions, such as Charity Shoals and North Shoal, where the females outnumbered the males, the population was composed largely of old fish.

Maturity and Longevity

Male bass begin to reach maturity at the end of the fourth year of life. Age group IV was the youngest group of mature males to

appear in the samples from the spawning runs, and a few ripe males of this age were taken in nearly every locality, although much larger groups of males were taken in ages beyond IV. The data do not reveal the youngest age group at which all of the males had reached maturity because immature fish were not represented in the spawning-run samples in proportion to their true numbers in the whole population. However, it is likely that nearly all of the males are ready to spawn by the time they are 6 years old. The smallest ripe male was taken at Linda Island and measured 7¾ inches in length, but very few males mature at less than 10 inches, and possibly some are still immature at 12 inches.

Female bass begin to reach maturity at the end of the fifth year of life, but spawning females of this age are rare. They first begin to appear in numbers in age group VI and apparently do not all mature until about 8 or 9 years of age, the age at which both sexes were equally abundant in the spawning runs. The smallest ripe female was taken at Eel Bay and measured 10⅛ inches in length, but relatively few mature at less than 12 inches, and possibly some are still immature at 14 inches.

The oldest bass taken were three female fish which were 14 years old. These fish were taken at Charity Shoal, Eel Bay, and North Shoal. Relatively few fish were taken in age group XIII, but in some localities a considerable number of fish had reached an age of 12 years. For example, in the sample of 177 fish taken at Charity Shoal in 1950 there were 83 fish in age group XII or approximately 47 per cent of the sample. Probably many of these fish were destined to be removed from the fishery by natural mortality due to old age rather than by being caught by anglers. It is interesting to note that some males lived just about as long as the females even though females were more numerous among the older age groups.

Natural Reproduction

There is considerable variation in the spawning time of the bass in this region. Relatively early spawning (latter part of May or early June) is characteristic of the bass which ascend the streams, spawn near the creek mouths or enter the shallow waters of some of the bays. But it is certain that some bass do not spawn until the latter part of June or well into July, particularly those fish influenced by the cold water of Lake Ontario. Water temperature is considered to be an important factor controlling the spawning time of bass. Hubbs and

Bailey (1938) state that smallmouth bass spawning occurs at water temperatures of 59° to 65°F.

Stony Creek, which enters Lake Ontario just south of Stony Point, is an example of an early stream-spawning area. However, there are few such streams in the region and further study would be necessary to determine their role in the maintenance of bass fishing.

Millen Bay (Figure 4) is typical of some of the early bay-spawning grounds. Observations were made on 16 bass nests in this bay during the period June 15-30, 1948. Ten nests were located along the protected west shore on June 15. The nests were hollowed-out, circular excavations (1½ to 2½ feet in diameter) on a gravel bottom at depths ranging from 1½ to 3 feet of water. They were located at distances of 10 to 30 feet out from shore. On June 15 water temperatures varied from 63° to 70°F. and during the following week an additional six nests were established. Guarding male bass were seen on 13 of the 16 nests at least once. Eggs were observed on all but two nests. The first fry appeared among the gravel of one nest on June 23 while the first black fry rose off the bottom on June 25. Seven of the 16 nests (44 per cent) hatched fry. Nine of the nests were abandoned and became covered with silt or overgrown with filamentous algae before the fry hatched. Possibly some of the guarding male bass were removed by angling.

An appreciable amount of spawning activity apparently occurs in the region of Eel Bay during the first two weeks of June. In the years 1948 and 1949 water temperatures in Eel Bay varied from 61° to 65°F. while 40 per cent of a total of 184 female bass netted were ripe. One group of advanced fry was observed in the bay on June 22, 1948.

In most years, water temperatures in the open lake would run much less than 60°F. during the first two weeks of June. Water temperatures at Charity Shoals on June 2 and 6, 1949 were 54° and 53°F., respectively, and all female bass examined during tagging operations were hard. Although no observations were made on spawning activities at Charity Shoals it is reported by commercial fishermen that bass do spawn there. Examinations of bass netted during the first two weeks of June from Wilson Bay and the off-shore localities in Lake Ontario showed that most of the females were hard. Of a total of 746 gravid females examined only six fish (0.8 per cent) were ripe.

A wide search was made during the period June 15-28, 1948 for evidence of bass spawning. The following areas in the St. Lawrence River, all containing suitable gravel bottom for spawning, were

inspected: Dodge Bay, the bay at Cedar Point State Park, a small bay just west of Burnham Point, Carleton Island, Sand Bay, Linda Island, Beadle Bay, and the territory around Bluff, Murray, Picton, and Grindstone Islands. Only four bass nests were found during this survey. They were located as follows: one nest in the bay at Cedar Point State Park, one nest along the east shore of Beadle Bay, and two nests along the north shore of Grindstone Island. Additional areas adjacent to Lake Ontario were checked. They were: Wilson Bay, Mud Bay, Point Peninsula, and Three Mile Bay. However, no evidence of bass spawning was observed in these areas during the June survey. There are several possible explanations for the small amount of spawning activity observed in the areas mentioned above.

1. The period between June 15 and June 28 was too early for the bulk of the inshore populations to be at the peak of spawning activity.
2. There was an extensive spawning period, i.e., only a few fish spawned at one time.
3. The majority of bass spawned in deeper water where the nests could not be observed.
4. Spawning was scattered over a large expanse of shoreline. Reports from guides indicate a greater extent of suitable spawning area on the Canadian side of the river. This area was not investigated during this study.

To determine the success of bass spawning in the region, surveys of young bass were conducted in September 1948 and August 1949. During September 1948 young-of-the-year bass were taken by angling with artificial flies in the vicinity of Carleton Island and Linda Island. These small fish were caught where water depths ranged from 15 to 20 feet. None was found in shallow water close to shore. During August 1949 young bass, 1½ to 2⅛ inches in length, were seined in the vicinity of Linda Island, Dodge Bay, and Carleton Island. However, none was taken in Sand Bay, Beadle Bay, Poplar Tree Bay, Point Peninsula, Wilson Bay, Eel Bay, or the bay at the mouth of Fox Creek.

As may be seen from Table 10 there appear to have been dominant year classes in the bass from Wilson Bay. Young bass produced in the years 1938 and 1939 comprised 65 to 75 per cent of all the bass netted from this area in the years 1945, 1947, and 1948. These dominant year groups reflect differences in the success of spawning or survival of the young fish in different years and stages of development.

TABLE 10. YEAR-CLASS FREQUENCY DISTRIBUTION OF WILSON BAY BASS ACCORDING TO SAMPLES OBTAINED IN THE YEARS 1945, 1947 AND 1948

Year class	Year of recovery								
	1945		1947		1948		1945	1947	1948
	Age group	Number	Age group	Number	Age group	Number	Percentage of sample	Percentage of sample	Percentage of sample
1943	II	...	IV	10	V	2	....	2.1	2.6
1942	III	...	V	20	VI	1	....	4.1	1.3
1941	IV	3	VI	73	VII	16	0.8	15.1	21.0
1940	V	13	VII	41	VIII	3	3.7	8.5	4.0
1939	VI	115	VIII	139	IX	18	32.5	28.8	23.7
1938	VII	154	IX	176	X	31	43.5	36.5	40.8
1937	VIII	40	X	21	XI	3	11.3	4.3	4.0
1936	IX	12	XI	3	XII	2	3.4	0.6	2.6
1935	X	13	XII	...	XIII	..	3.7	....	....
1934	XI	3	XIII	...	XIV	..	0.8	....	....
1933	XII	...	XIV	...	XV	..	....	....	....
1932	XIII	1	XV	...	XVI	..	0.3	....	....
Total		354		483		76	100.0	100.0	100.0

CONCLUSIONS

In future bass management in the Lake Ontario-St. Lawrence River region consideration should be given to the fact that the bass population as a whole is not homogeneous but is composed of a number of local populations. The main criteria used to distinguish local groups of bass were rate of growth and migration. Distinct bass populations can be recognized for Eel Bay, Wilson Bay, Charity Shoals, Chaumont Bay and the Galloo-Stony Island area. It appears that the river bass in the Carleton-Linda Island area are for the most part one population although there probably are small local groups around both of these islands.

It appears that the bass of the inshore area of the lake in proximity to the head of the St. Lawrence River, i.e., such areas as Wilson

Bay, contribute appreciably to fishing in the St. Lawrence River above Clayton.

Despite a heavy take of bass at Charity Shoals during June there is no evidence to show that this fishing adversely affects the abundance of this bass population. This conclusion is supported by the fact that the older age groups of bass were strongly represented in the samples studied. If some of these bass were not harvested during June it is probable that more would be lost to natural mortality. This conclusion may also be applied to North Shoal. In the other areas, with the exception of Eel Bay, the June catch is relatively small. Of the Eel Bay bass, however, there appears to be an appreciable amount of spawning before the June 16 opening date for bass fishing.

If in subsequent years a change in condition warrants additional protection to the bass during June such concentration areas as Eel Bay, Wilson Bay, Charity Shoals, and North Shoal could be given special consideration.

In the St. Lawrence River and to some extent in the open lake competition of the bass with other species, particularly rock bass, appears to be an important limiting factor.

LITERATURE CITED

Greeley, John R. 1940. Conservation of the black bass resource of the Lake Ontario-St. Lawrence region. New York State Cons. Dept.

Hile, Ralph. 1941. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts and Lett. 33:189-337.

Hubbs, Carl L. and Reeve M. Bailey. 1938. The smallmouth bass. Cranbrook Inst. of Sci. Bull. 10:37-40.

Snyder, J. P. 1932. Tagged smallmouth black bass in Lake Ontario. N. Y. Trans. Amer. Fish. Soc. 62:380-381.

A STUDY OF CRITERIA FOR ESTIMATING THE AGE OF BEAVERS[1]

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ABSTRACT

By recording changes in the developing skulls of known-age beavers on X-ray plates, constant changes were noted which can be correlated with age. Between 5 and 5½ months the third molars erupted. At 6 months, these teeth were fully grown. At 9½ months of age the permanent, developing premolars were visible below their predecessors. At 10½ months the deciduous premolars appeared as caps over the permanent ones. These caps were shed at 11 months and at 12 months the permanent premolars were level with the other molariform teeth. After 12 months the teeth were valueless for estimating age.

The age of beavers between 1 and 2 years old can be estimated by adding the maximum height of the sagittal crest to arbitrary values assigned the mounds of the maxillary bones over the cheek teeth of one side. Values applied to this latter character are as follows: four mounds were given a value of one; three mounds a value of two; two, a value of three; one, a value of four; and a level maxillary surface, a value of five.

Tail width, weight, and ossification of the tips of the long bones were of no value in defining age.

In addition to the study of the known-age beavers, 4,328 beaver skulls taken in 1948 by New York State trappers were studied. These skulls were aged according to the procedures outlined above, following which a series of skull measurements was taken. Except for defining ages of beavers 1 year old or less, these measurements were too variable to be of value for estimating beavers' ages.

A method for estimating age together with a random collection of skulls would make possible an appraisal of the age composition of the population from which the sample was taken. This assumes, however, that certain variables can be accurately assessed.

In the study of vertebrate populations an accurate method for determining ages of individuals observed is requisite if one is to describe the character of these populations in terms of annual increment and loss. Bradt (1938) and Shaw (1948) considered the magnitude of weight and/or tail dimensions as indices for determining ages of beavers. Grinnell *et al.* (1937) noted beaver age groups based on body measurements, tooth replacement, and weight data. Morgan

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(1868) and Seton (1926) suggested that beavers live for 12 to 15 years.

Many definitive studies of the processes of aging among mammals have dealt with laboratory rodents, in particular white mice and rats. Bloom and Bloom (1940) studied changes in the bones of embryonic and new-born rats. Silberberg and Silberberg (1941) evaluated changes related to age in bones and joints of several strains of mice and later (1945) they appraised the influence of sex and breeding on skeletal aging of these rodents. Crabtree (1941) considered the structure of Bowman's capsule as an index to the age of mice.

Among wild animals, Friley (1949) suggested that changes in baculi of beavers offered a valid basis for estimating age. Osborne (1953) concluded that certain skull and body measurements made possible the aging of Wyoming beavers. Alexander (1951), in his thoughtful study of muskrats in central New York, evaluated anatomical and reproductive data as they apply to the age of this fur-bearer. Severinghaus (1949), working with the white-tailed deer, defined procedures whereby tooth replacement and wear could be used to delimit age groups. Coues (1877), Deansely (1935), Grinnell *et al. (op. cit.)*, and Marshall (1951) considered the height of the sagittal crest of mustelids to be related to age.

The conclusions reached by many of these workers have resulted from planned sacrifice of experimental animals. With those fur-bearers, such as the beaver, which are rarely kept as pets or bred in captivity, it is difficult to obtain known-age material. However, it is possible to live-trap beaver kits and mark (ear-tag) them prior to liberation. An attempt can then be made to recover marked specimens taken by trappers and thus secure known-age carcasses for study. Such a program has been in operation in New York State since 1948 in connection with nuisance-control operations but to date no specimens have been recovered. To obtain data on skeletal changes, an alternative is to raise specimens in captivity from birth and record on X-ray plates those features which might reveal diagnostic data for judging age. Results from a study of this nature are reported here, together with an age analysis of a large sample of beaver skulls collected during the 1948 trapping season in New York.

PROCEDURE

Some of the methods employed in this study involve procedures which must be covered in some detail if the limitations of the data are to be fully appreciated and understood.

Known-age Beavers

On May 22, 1949, a pregnant beaver was live-trapped near Poughkeepsie, New York and transferred to the Wildlife Research Laboratory where she was held in an outdoor pen. During the night of May 25, 1949, she gave birth to four female kits. These young were held with their parent in the outdoor pen until early fall. At that time, the adult was sacrificed and the immature beavers transferred to an indoor enclosure where they remained until approximately 3 years old.

This known-age group was fed aspen and commercial rabbit pellets, the latter from a hopper. A constant source of water was supplied.

Each was marked with a small, numbered, monel-metal ear tag which was affixed to the leading edge of the ear near its root. Once fastened in this position, the tags caused the beavers no apparent discomfort; at least they never were observed trying to remove them.

Roentgenology From October, 1949 to September, 1950, each beaver was X-rayed at monthly intervals at which times X-ray plates showing the lateral aspect of the skull and the proximal portion of the femur were exposed. Between September, 1950 and February, 1952, the animals were X-rayed at irregular intervals.

To hold the X-ray plates, 5 x 7 inch cassettes with intensifying screens were used. For recording changes in the lateral aspect of the skull, a right-angled wooden form was used to help position the beaver's head, reduce movement of the subject, and hold the cassette in a vertical plane.

The region of the proximal portion of the femur was recorded by first securing the cassette with adhesive tape to the base of the X-ray head holder. A beaver was then lifted and positioned on the plate. To immobilize the subject, one person held the beaver behind the forelegs and around the thorax. Another grasped the rear feet, extending them to the rear so that both feet and the base of the tail might be securely held during exposure.

Using intensifying screens and a 3-inch radiographic cone having a 2-inch aperture and operating the X-ray head at 12 milliamperes and 120-125 volts, the following exposures produced satisfactory results:

Skull —½ second at 3 inches from the X-ray head
Femural region—¾ second at 20 inches from the X-ray head

Measurements and Other Observations Recorded After December, 1949, as the known-age beavers were X-rayed, each was weighed and the dimensions of the naked portion of the tail were recorded. All linear measurements, except for tail width, were taken with vernier calipers.

X-ray plates furnished information on tooth replacement and growth, changes in the topography of the maxillary surface and in the height of the sagittal crest. The height of the sagittal crest was measured directly from the plates.

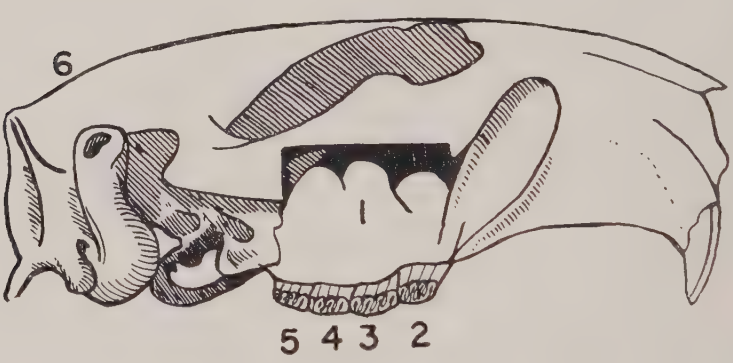

Figure 1. Skull of 11½-month-old beaver showing mounding of bone over molariform teeth. Note the relative length of the permanent premolar and the molars.

Arbitrary values were given the mounds of bone above the upper cheek teeth (Figure 1). When all four of these teeth on one side showed mounds of bone above them, a value of one was given. When this condition was observed for three of these teeth, a value of two was given; for two teeth a value of three; one tooth a value of four; and when the maxillary surface was level above the grinding teeth, such a skull was given a value of five. This value was then added to the height of the sagittal crest, resulting in a unit which may be related to age.

Unknown-age Beaver Skulls

During March, 1948, New York State trappers harvested 4,328 beavers. Under Conservation Department order each trapper was required to forfeit a beaver head to a game protector with each pelt he offered for tagging. These heads were shipped to the Wildlife Research Laboratory, Delmar, New York, and were prepared for later identification by passing a wire, which held a numbered metal tag, through the zygomatic arch and around the dentary of the same side. The heads were then placed in wire mesh enclosures, covered with burlap, and left outdoors during the summer of 1948 to be cleaned by insect larvae.

In estimating the age of these skulls, the height of the sagittal crest was measured with a vernier depth gauge as shown in Figure 2.

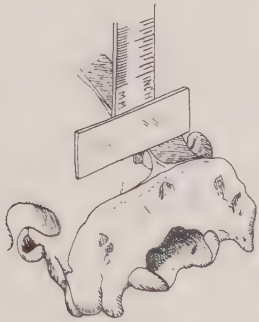

Figure 2. Method of measuring the height of the sagittal crest

Other skull measurements (Figure 3) and observations which were taken from this group of skulls follow: alveolar length, greatest length of skull, width of incisors, width of the temporal ridges, palatilar length, zygomatic breadth, mastoid breadth, intraorbital width, width of the rostrum, length of the nasal bones, width of the nasal bones, height of the skull, and the relative character of the surface of the parietals as to smoothness or roughness. Also, values were given the mounds of bone above the cheek teeth according to the same method used for the known-age specimens.

FINDINGS

The teeth of beavers are typically rodentiform with the exception that the deciduous premolars are rooted whereas their successors are rootless (Figure 4). The deciduous teeth generally have three roots.

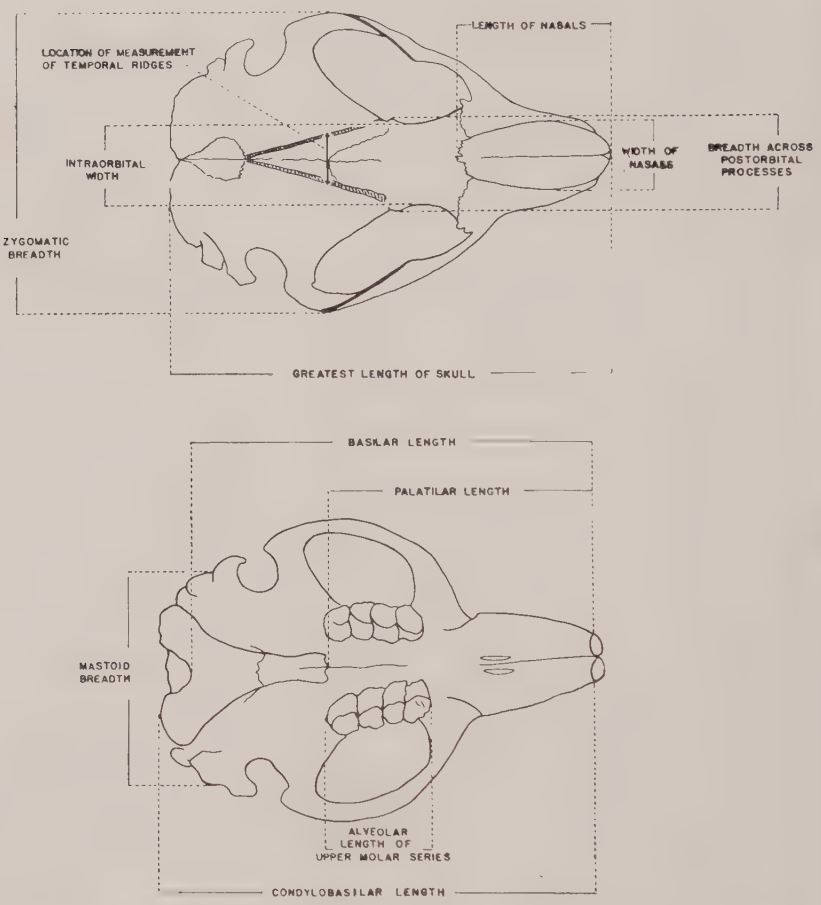

Figure 3. Dorsal (above) and ventral (below) aspects of beaver skull illustrating measurements taken

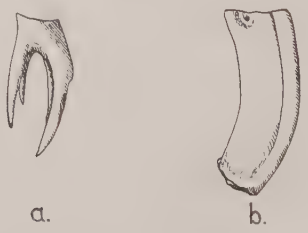

Figure 4. Examples of premolar teeth of beaver (from the maxilla): a. rooted (deciduous); b. rootless (permanent)

Those from the maxilla have a broad, flattened, single root on the lingual side while on the buccal surface two roots are present. The latter are shorter, generally oval in cross-section, and somewhat acute at their dorsal ends. The deciduous premolars from the dentaries have two or three roots. A large, flat root secures the tooth caudally while a round or flat root of equal length occupies the forward part of the socket. Arising from the latter may be a short, acute projection which enters the dentary approximately midway between the two main roots.

The crown of a molariform tooth is formed by a continuous, thin, convoluted line of enamel inside of which is the more deeply-colored dentine (Figure 5). In the maturing molar the height of the enamel

Figure 5. Skull of 5½-month-old beaver showing eruption of third molar

ridges above the dentine is pronounced, but, when mature, both components are at approximately the same level (Figure 1). The crown area of a deciduous premolar approximates that of the third molar while the crown area of the fully-grown, permanent premolar is decidedly greater than that of any of the molars.

Known-age Beavers

Observations made on this group resulted in criteria used for aging the series of skulls collected by trappers. Consequently a definition of dental and skull changes of these will be presented before an analysis is made of the larger series.

Tooth Replacement and Growth Among the four known-age individuals, tooth replacement and growth showed little or no variation.

Changes in dentition as recorded on X-ray plates seem to furnish reliable evidence for aging beavers up to 12 months old. Between 5 and 5½ months of age the third molars erupted (Figure 5). These teeth were fully grown at 6 months. At 9½ months of age the crowns of the permanent premolars could be seen below their predecessors and at 10½ months the deciduous teeth appeared as caps over the permanent ones. These were shed by the end of the eleventh month. At 12 months the permanent premolars were fully grown and the crowns of the molariform teeth were approximately level.

After 12 months the permanent premolars from the dentaries were worn to a peak at their leading edges while the corresponding teeth from the maxillary bones were worn so as to occlude with their counterparts below (Figure 6.) After 12 months, tooth replacement, growth, and wear were valueless for determining age.

Changes in the Skull in Relation to Age The grinding teeth of beavers less than 2 years old are longer in relation to the height of the skull than those of beavers estimated to be 2 or more years of age.[2] The relatively long molar teeth of the younger group are accommodated in the comparatively low skull by thin, often-perforated elevations of the maxilla over the fangs (tooth roots) of one or more of the cheek teeth.

Throughout the first 16 months, pronounced elevations or mounds in the maxillary bones over the molariform teeth of the known-age beavers were evident (Figures 1 and 7). From this time on, an uneven leveling of these mounds resulted in the following inconsistencies: (1) mounds over the second and third molars; (2) mounds over the third molar only; (3) complete disappearance of mounds. After 3½ years, the skulls of two known-age beavers were completely free of protuberances in this area (Figure 8).

When considered alone, the value of the topography of the dorsal maxillary surface as a criterion for separating yearling from older beavers may be questioned because of the variabilities just mentioned.

[2] For example, an analysis of the specimens collected from trappers in 1948 afforded the following comparisons. For specimens estimated to be between 1 and 2 years old, skull height varied between 45.5 and 50.4 millimeters with a mean of 47.6 millimeters while the length of the second molar varied between 21.2 and 22.9 millimeters. In the group estimated to be 2 years old or more, the mean skull height was 57.8 millimeters while the mean length of the second molar was 19.7 millimeters.

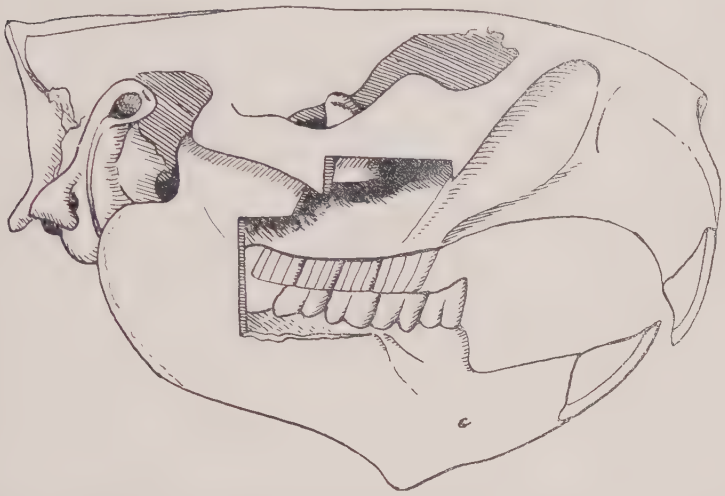

Figure 6. Skull of 3½-year-old beaver showing the peaking of the premolar from the dentary and normal occlusion

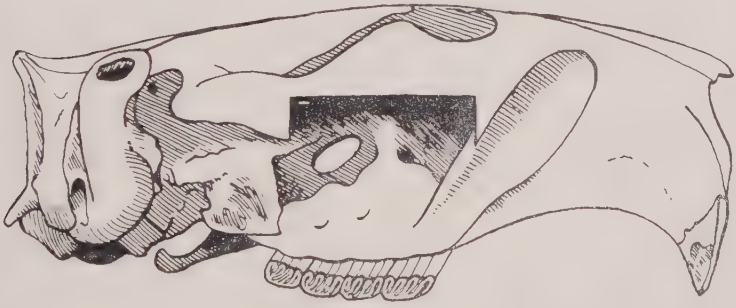

Figure 7. Skull of yearling beaver showing low mounding of the maxilla

Figure 8. Skull of 3½-year-old beaver showing level surface of the maxilla

When correlated with the height of the sagittal crest, an apparently reliable base was established for defining the yearling group.

Among the known-age beavers the height of the sagittal crest varied between 0.7 and 2.4 millimeters during their second year. The sum of the height of this crest and the value for the mounds of bone over the fangs of the molars (as described under Procedure) ranged between 3.7 and 7.4 units.

Tail Width and Age Tail width also has been considered as a means of estimating age of beavers. Among the known-age individuals, tail widths at 7½ months of age equalled or exceeded those given by Shaw *(op. cit.)* for the 3-year-old and older animals (Figure 9).

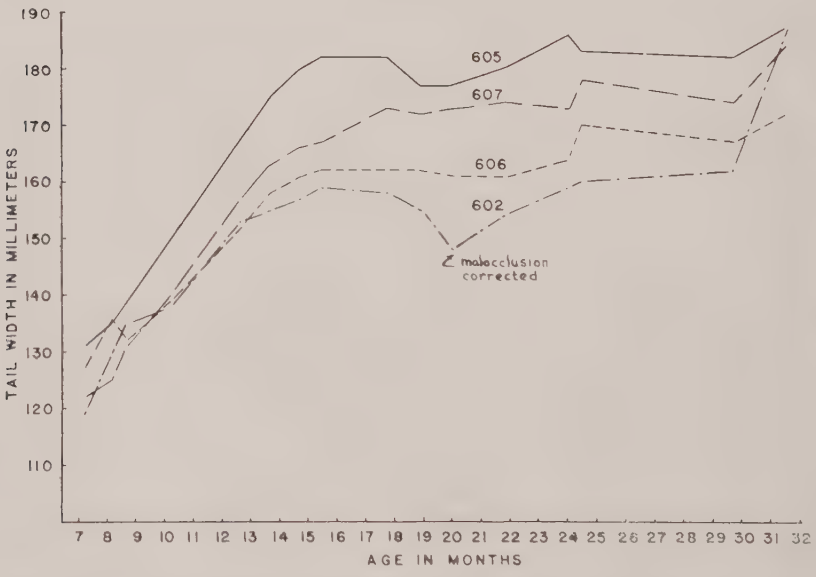

Figure 9. Relationship of age to tail width for four known-age female beavers

The maximum width of a beaver's tail may not constantly increase. Beaver #602 had a tail width of 186 millimeters just prior to release. Four months later this beaver was recaptured and its tail width was 146 millimeters. This decrease in tail width accompanied a loss in total weight. At release she weighed 18,550 grams and when recaptured 15,900 grams—a loss of approximately 5.8 pounds. This same beaver suffered from malocclusion during February, 1951 and the width of her tail decreased by 15 millimeters. Following incisor repair, the width increased sharply (Figure 9).

Growth The four known-age beavers used in this study continued to grow throughout the period in which they were held captive (Figure 10). Mrs. A. M. Richards of Dolgeville, N. Y., who has kept

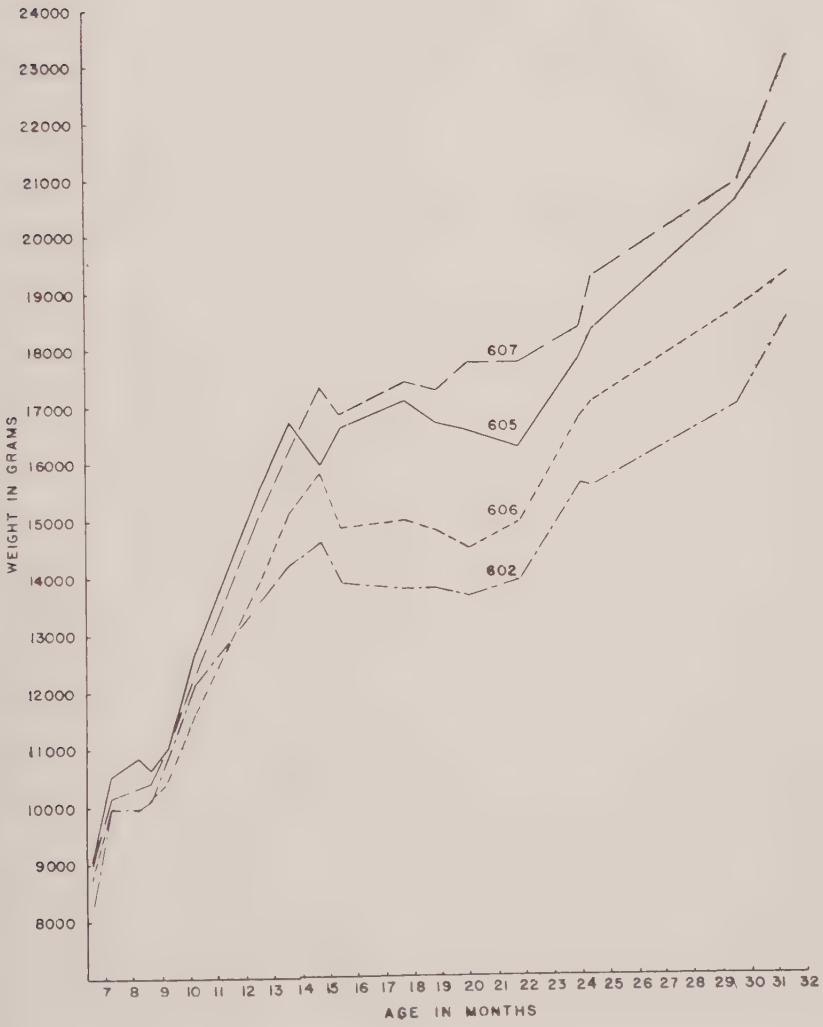

Figure 10. Relationship of age to weight for four known-age female beavers

beavers as pets for 20 years, thinks growth terminates at about 4 years. The heaviest New York beaver for which there are authentic data, an individual weighing 73.25 pounds, was trapped near Saranac Lake during the spring of 1949.

Weight in Relation to Age Weight limits for the yearling group, as defined by workers mentioned earlier, were equalled or exceeded before the known-age young were 8 months old (Figure 10).

Ossification of the Tips of the Long Bones The X-ray plates of the known-age beavers indicated changes in the epiphyseo-diaphyseal union of the femur. These changes might be defined adequately by cytological studies, but gross examination of this feature from X-ray plates did not reveal changes which could be used as criteria of age.

Unknown-age Beaver Skulls

Changes as defined for the known-age beavers have been applied to the skulls obtained from trappers in 1948. Tooth replacement was used to identify skulls from beavers 1 year old or less. The unit obtained by adding the height of the sagittal crest to the value for the mounds of bone over the molariform teeth was used to define the yearling group. The remainder were considered to be 2 years old or more.

For those estimated to be in the yearling group, the sum of the values for the sagittal crest and the mounding of the dorsal maxilla varied between 2.5 and 7.4 units with a mean of 4.84 and a standard deviation of 1.06. The index for this group as a whole overlapped that for those estimated to be 2 years old or more by 6.4 per cent while that for the latter group extended into the range of the yearlings by 7.0 per cent (Figure 11). Such overlapping does not negate the value of the index for the yearling group. It is distinctly different from that of the skulls of older beavers.

Beaver skulls with measurements falling outside the range noted above were estimated to represent beavers more than 2 years old. A mean with its standard deviation for this group would be meaningless as it may be assumed that ages in it varied from 2-plus to possibly 10 or more years.

As was mentioned earlier, a series of exploratory skull measurements was taken. Following completion of the study of the known-age beavers, these measurements were rechecked for a portion of the specimens in each group. The data, comparing beavers up to 1

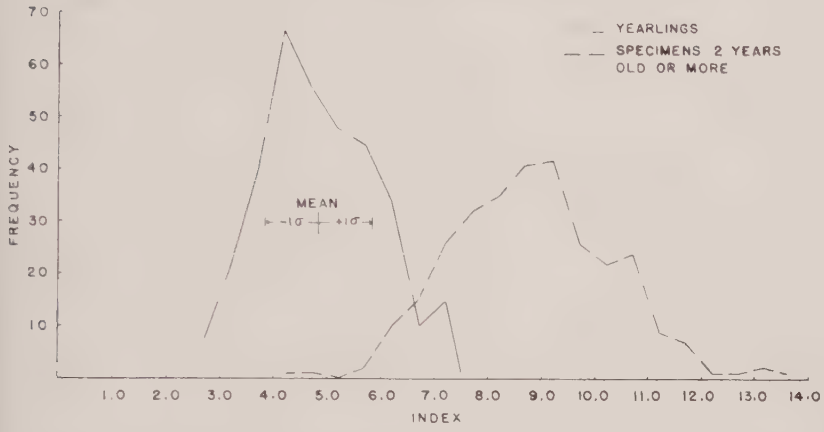

Figure 11. Comparative distribution, for yearling beavers (343 specimens) and those 2 years old or more (298 specimens), of the index representing the character of the sagittal crest and maxillary surface

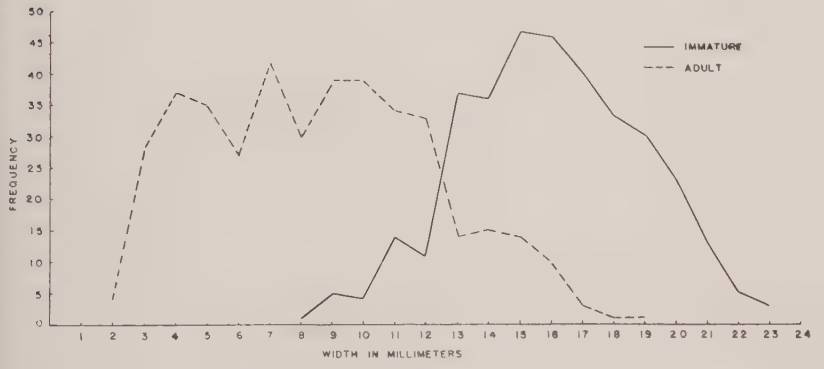

Figure 12. Width of temporal ridges recorded for 356 immature and 408 adult beavers

year of age with those older, are summarized in Table 1. Each measurement was highly variable and could not be related directly to changes as observed in the known-age beavers. When these measurements—or products obtained by multiplying two or more of them—were graphed for all the skulls originally measured,[3] clearly

[3] Because many of these specimens were fragmentary, the numbers involved with respect to the several measurements differed.

Table 1. Measurements (in millimeters) of Beaver Skulls in Relation to Estimated Age

Skulls examined and data recorded	Measurements considered												
	Alveolar length	Greatest length of skull	Width of incisor	Width of the temporal ridges*	Basilar length	Palatilar length	Zygomatic breadth	Mastoid breadth	Intra-orbital width	Width of rostrum	Length of nasal bones	Width of nasal bones	Height of skull
Immature§													
Number	79	68	77	77	5	74	74	10	79	78	74	72	23
Mean	28.1	108.5	5.6	16.7	90.2	60.3	74.6	52.7	21.7	19.2	36.7	18.8	36.7
Deviation†	1.6	5.7	0.4	3.4	7.2	3.2	3.7	2.8	1.1	1.1	2.5	1.3	2.1
Adult§													
Number	94	90	94	91	82	94	90	83	92	93	88	87	90
Mean	32.4	129.4	7.1	9.2	114.9	72.7	91.5	62.7	24.4	23.5	45.4	23.0	42.2
Deviation†	1.6	7.7	0.5	4.0	7.8	4.7	5.3	3.4	1.6	1.6	3.4	1.7	2.3

* Measured at the caudal end of the frontal bone.
§ Immature specimens were considered to be those in which the premolars were not fully erupted; adult specimens, those with fully developed molariform teeth.
† Standard deviation of the mean.

defined peaks that might indicate year classes did not appear in the resulting curves for beavers older than 1 year. Some of these relationships are shown in Figures 12, 13, and 14.

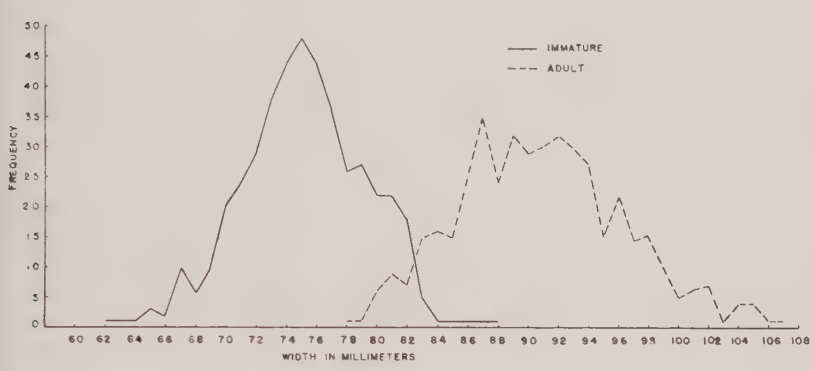

Figure 13. Zygomatic width recorded for 425 immature and 445 adult beavers

The greater variability of the curves depicting the adult group may represent the influence of several age classes. Interpretation of these data is impossible with the limited available knowledge of the characteristics of the older age classes.

Age Composition of the 1948 Beaver Harvest Three age groups were recognized in the trappers' harvest: individuals 1 year old or younger, those between 1 and 2 years (yearlings), and those 2 years old or more. Of the 4,328 beavers taken, 56.4 per cent were 1 year or less old, 23.3 per cent were between 1 and 2 years of age, while 20.3 per cent were 2 years or older. Records of Mr. Joseph Buff, Syracuse, New York—a fur buyer for 53 years—indicate that young of the year represent about 65 per cent of the total harvest. Buff's estimate is predicated on pelt size.

Pelt Size and Age At the time game protectors tagged the beaver skulls, the maximum width and length of the pelts were also recorded. When figures for total length or total width or a product of the two values were plotted, no peaks appeared in the graphs which might indicate age groups. It was not possible to relate pelt-size data to the measurements of skulls for which the age had been estimated. There is much evidence in the data to indicate that pelt-sizes recorded by protectors did not always correspond to the skulls to which the pelt data were attached. Moreover, because of great variability in

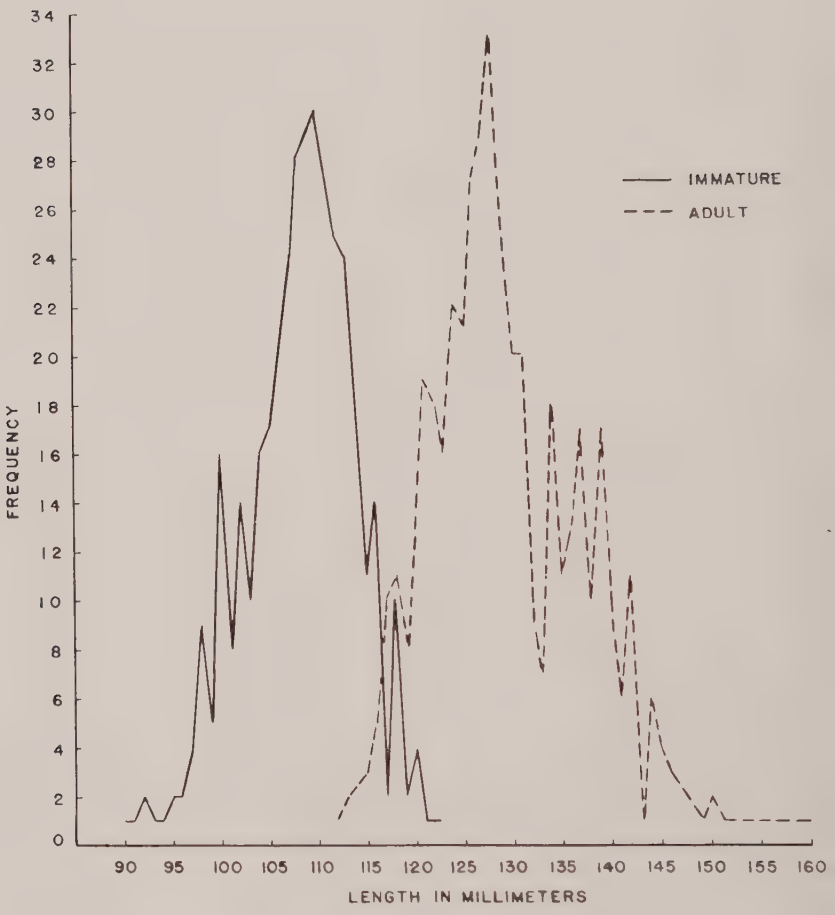

Figure 14. Total length of skull recorded for 378 immature and 452 adult beavers

methods of handling raw beaver pelts, it seems likely that pelt size could not be related directly to age.

Period of Birth The 2,441 immature beavers taken by trappers in 1948 were born between late March and November, 1947. For seven specimens the period of birth could not be determined because of damage to the skulls. Of the remainder, 7 (0.3 per cent) were born from late March to mid-April, 1,589 (65.3 per cent) in late April and May, 757 (31.1 per cent) in early June, 78 (3.2 per cent) in late June, and 3 (0.1 per cent) in November. These birth periods

are considered to be accurate within 2 weeks. Periods of birth as noted, correspond closely to those indicated in data furnished by Mrs. Richards, who has observed and recorded litter birth dates for over a 20-year period. Her beavers have given birth to young in March, April, May, August, and December. George Davis of the Vermont Fish and Game Service has reported (correspondence) that a wild-trapped female gave birth to a litter in December while on display at a sportsman's show.

DISCUSSION

One logical criticism of this study might be the fact that only four beavers - all captives and all females—were used as a basis for defining beaver age characteristics betwen 6 months and 2 years. In general the growth-depressing influences of estrogens may result in sexual dimorphism among mammals. Furthermore, this influence would have been constant in the study specimens because they were never bred. However, disparity in size between sexes has not been observed among beavers, and it may be assumed that growth rates of the sexes are similar.

Growth rates as observed for the four known-age captives may represent the potential that might result under ideal or near-ideal natural conditions. There has not been an opportunity to obtain weights of wild-reared beavers of known age since aging knowledge has been available. Consequently, weights of beavers reared under natural conditions cannot be compared at this time with those of animals raised in captivity.

Osborne *(op. cit.)* apparently assumed that age was directly related to size. This basic assumption is not necessarily valid as growth rates, within genetic limitations for the species, may be and probably are dependent on habitat quality.

The evidence presented here suggests that, among its other functions, the tail of a beaver serves as a fat storage organ. If this conclusion is correct, tail width more clearly defines condition than age.

It seems logical to assume that replacement and growth of teeth would be more closely allied with changes in age than with the general, overall growth pattern. This has been demonstrated by Pope (1934) for horses, mules, cattle, sheep, goats, and swine, and by Severinghaus *(op. cit.)* for the white-tailed deer.

After the first year, changes in cranial features, including the mounds of the maxilla over the molariform teeth and the height of the sagittal crest, seem to be correlated with age. However, methods

defined in this paper for estimating the ages of beavers beyond 12 months must be considered of tentative value until additional, known-age skulls of yearlings and beaver between 2 and 3 years old can be obtained for study.

It is impossible with the data at hand to appraise the age composition of the population from which the 1948 harvest was taken. Trapping is generally considered to be non-selective, since one animal is as apt to be caught as another. But apparently, with beavers, this does not apply.

In New York State a variety of traps, ranging in size from No. 2 to No. 4 is used to take beavers. For any particular trap size a large beaver would be more apt to escape than a small one, or proportionately more yearlings would likely be removed from the population than older animals. This is substantiated by the authors' experience as well as the desire on the part of beaver trappers throughout the State to legalize or devise more effective beaver traps. Further, beavers injured by a trap are difficult to retrap, at least for the remainder of the season in which they have been injured. These observations tend to negate the assumption that the percentage of individuals for each group in the 1948 trappers' harvest represents the relative composition of the population prior to the trapping season.

The age composition of the beaver harvest in 1948 cannot be used to predict future harvests or to explain the results of trapping during previous years. In 1947 beaver trapping was not permitted. Consequently, the age composition in 1948 probably differed from that which would have been observed had the 1947 population been subjected to trapping pressure.

There are additional variables difficult to assess. High pelt values stimulate trapping. Adverse weather may reduce trapper effort, particularly in remote areas. Trapping pressures may be, and probably are, variable between years for each of the several political subdivisions in the State. These inconsistencies tend to make a theoretical prediction of the population, based on the number of beaver pelts tagged, relatively meaningless when the age composition has been estimated for only one season.

On the other hand, a knowledge of the age composition of beavers in a trapped population for a series of years would make possible an estimate of the population that produced the harvests. This assumes that trappings pressures, sex ratios, reproductive rate, and the selective trapping of young beavers could be evaluated.

Through aging, birth dates may be determined. During nuisance-control operations, live-trapping just prior to or immediately following the peak of parturition would probably result in unwarranted losses. These could be avoided or reduced if timing of live-trapping and transfer could be based on a better knowledge of the birth season.

Aging makes possible, for any biotic area, an appraisal of reproductive success, providing an annual, random collection of skulls may be obtained. This could lead, indirectly, to an evaluation of habitat quality for beavers which would, in turn, increase the value of morphological studies of the species. For example, the beavers now in New York State are the result of a mixture of the native stock and importations from other widely-separated areas. A study of relationships between the New York State population and other more homogeneous races would be of interest to taxonomists, game managers, and members of the fur industry.

CONCLUSIONS

Beaver ages between 5 and 12 months may be estimated within one month by tooth replacement and growth. From 12 months on, more known-age material must be studied before absolute confidence can be placed in the value of the sum of the sagittal crest and the mounds of the maxillary for defining the age of beavers.

LITERATURE CITED

Alexander, M. M. 1951. The aging of muskrats on the Montezuma National Wildlife Refuge. Jour. Wildl. Mgt. 15(2):175-185.

Bloom, William and Margaret A. Bloom. 1940. Calcification and ossification: Calcification of developing bones in embryonic and newborn rats. Anat. Rec. 78(4):497-523.

Bradt, Glenn W. 1938. A study of beaver colonies in Michigan. Jour. Mammal. 19(2):139-162.

Coues, Elliot. 1877. Fur-bearing animals. U. S. Dept. Int., Misc. Publ. No. 8.

Crabtree, Charlotte. 1941. The structure of Bowman's capsule as an index of age and sex variation in normal mice. Anat. Rec. 79(3):395-413.

Deansely, R. 1935. The reproductive processes of certain mammals: Part IX, Growth and reproduction in the stoat *(Mustela erminea)*. Philos. Trans. Roy. Soc. London, Series B, 518, Vol. 225:1-62.

Friley, Charles E. 1949. Use of the baculum in age determination of Michigan beaver. Jour. Mammal. 30(3):261-267.

Grinnell, Joseph, J. S. Dixon, and J. M. Linsdale. 1937. Fur-bearing mammals of California, Vol. 2. Univ. Calif. Press, Berkeley.

Marshall, William H. 1951. An age determination method for the pine marten. Jour. Wildl. Mgt. 15(3):276-283.

Morgan, L. H. 1868. The American beaver and his works. J. B. Lippincott Co., Phila.

Osborne, Dale J. 1953. Age classes, reproduction, and sex ratios of Wyoming beaver. Jour. Mammal. 34(1):27-44.

Pope, George W. 1934. Determining the age of farm animals by their teeth. U. S. Dept. Agr. Farmers Bull. 1721.

Seton, Ernest Thompson. 1926. Lives of game animals. Vol. 4. Doubleday, Page and Co., New York.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. Jour. Wildl. Mgt. 13(2):195-216.

Shaw, Samuel P. 1948. The beaver in Massachusetts. Mass. Dept. Cons. Res. Bull. 11.

Silberberg, Martin and Ruth Silberberg. 1941. Age changes of bones and joints in various strains of mice. Amer. Jour. Anat. 68(1):69-95.

———————. 1945. The influence of sex and breeding on skeletal aging of mice. Anat. Rec. 91(2):89-101.

REACTIONS AND MOTION OF FISH IN A DIRECT CURRENT ELECTRIC FIELD[1]

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ABSTRACT

Because the use of direct current has definite advantages in the collection of fish by electrical means, a study was undertaken of the reactions of fish subjected to this type of current. It was found that the migration of fish to the positive electrode in the direct current shocker technique is involuntary. The motion toward the positive pole is believed to result from shock to the nerve endings in the muscles. Steady direct current modifies the normal swimming motion and guides the fish toward the positive pole. Intermittent direct current causes an involuntary motion consisting of a turn toward the positive pole and forward motion at each circuit closure. The motion resulting from intermittent current is more pronounced than that produced by steady current. The intermittent effect requires a lower voltage than that of steady current. Therefore, intermittent direct current may be effective for lower line voltages and greater electrode separations than steady current.

To combine the effects of steady and intermittent direct current a cycle of 0.8 second on followed by 0.2 second off is tentatively recommended. The voltage rise on circuit closure must be rapid.

Theoretical physiological considerations are discussed which indicate a possibility that several hundred pulsations per second may be practical. This rapid rate of pulsation might be combined with a slow on and off cycle.

The use of direct current constitutes one of the more recent advances in the collection of fish by electrical means. Since the fish are "attracted" to the positive electrode, the method has definite advantages especially in waters where visibility is poor or where it is difficult to recover fish due to obstructions in the stream. The present study dealt with the mechanism of attraction to the positive electrode.

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The authors are greatly indebted to Drs. H. H. Dodds, Utica, N. Y., R. S. Hunter of the Hartford Branch of the University of Connecticut, and Wallace O. Fenn and E. B. Wright of the University of Rochester for advice on the effect of shock on nerves and muscles. Dr. Perry W. Gilbert of Cornell University gave helpful advice about the muscular structure of fish and the mechanism of "normal" swimming. Various members of the New York State Conservation Department have aided in many ways. In particular thanks are due to Dr. C. W. Greene, who carefully edited the manuscript, Dr. L. E. Wolf who assisted in the dissections, and Earl McGuirk, of the Division of Conservation Education, who handled the unusual photographic problems.

Direct current methods for fish collection were reported by Rayner (1949, 1950) who described the experimental work of Dr. Kurt Smolian in Germany as well as his own experiments. Of the several American workers who have used and have aided in the development of the direct current technique, Rayner appears to have been the most active.

Briefly the method consists of a two-electrode system connected to a direct current generator. The negative generator lead may be grounded or connected to a paddle-type electrode. The positive electrode may be a paddle but preferably a scap net interlaced with copper wire. The fish swim to the positive pole and are easily captured. If a scap net is used as the positive electrode, they often swim into the net.

Rayner (1949) found intermittent current to be more effective than continuous current and Houston (1949) described the work of a German physicist, Konrad Kreutzer, who found that the current, for maximum effect, must be built up suddenly and allowed to taper off with a pulse of about .002 second. By varying the time between pulses to coincide with the natural swimming motion of fish of a particular size, Kreutzer found the apparatus could be used selectively for one size group. More recently Peterson (1952) has described the latest fishing boat employed by Kreutzer for salt water use where very short impulses are employed at extremely high currents.

Preliminary experiments revealed that under uniform laboratory conditions the "drawing" effect of direct current was very erratic. Although certain fish were quickly attracted to the positive electrode, others either were not affected or made only a portion of the desired migration. It was, therefore, deemed necessary to determine the mechanism of the attraction in order to understand this variation in response.

In planning the work two limitations were deliberately imposed. First, it was decided to collect only such data as might directly apply to shocker work. Second, since in all stream census work it is more difficult to shock small fish, the study was limited to fingerlings with minimum size of 3½ inches. The studies were carried on at the Rome Fish Hatchery. All experiments were repeated many times, and, since each fish responded to only a few shocks, several hundred fish were used.

For simplicity throughout the remainder of this paper the word "fish" will refer to brown trout.

EXPERIMENTS WITH FISH OUT OF WATER

A fish was removed from water and allowed to lie on a table until quiet. Two probes were connected to a source of direct current of about 20 volts. The negative probe was held on its head, with the fish lying on its side on a table. The positive probe was then touched to the upper side of the body near the tail. At the instant of contact the tail[2] flipped up away from the table (Figure 1). The motion was

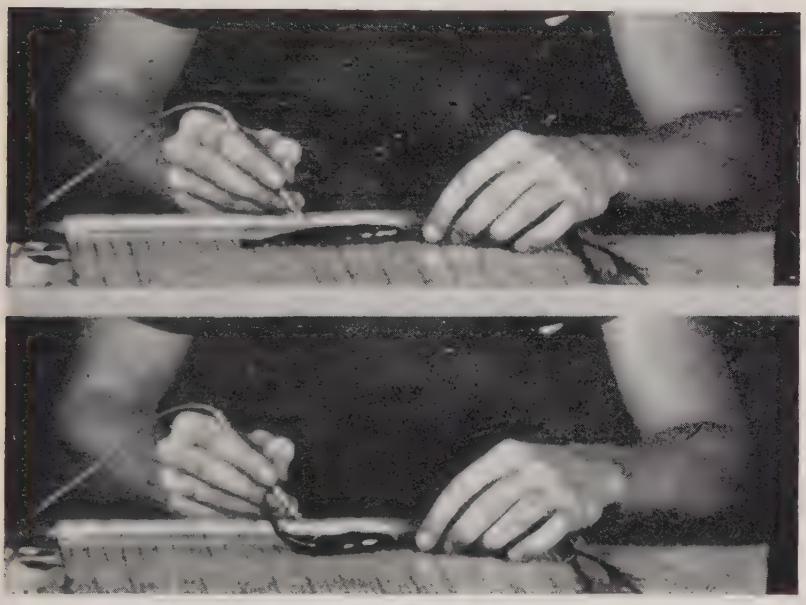

Figure 1. Motion of pithed brown trout due to direct current shock when negative electrode is held on head and positive is touched to tail. Upper picture is before shock; lower picture after shock.

repeated each time the positive probe was touched to the same part of the fish, and although the motion gradually became less vigorous it was always upward.

If the negative probe was held near the tail, and the positive electrode touched to the upper side of the body near the head, the head flipped upward. The motion was repeated each time the fish was touched with the positive electrode.

[2] Throughout this paper, motion of the "tail" refers to motion of the posterior end of the fish rather than the caudal fin alone. Similarly, bending or motion of the "head" refers to motion of the anterior portion of the fish, including more than merely the head.

On the other hand, if the positive electrode was held on the head and the negative pole touched to the upper side of the body near the tail, the tail tended to bend downward, but, since the fish was on a table, the tail pressed against this surface thus causing the center or mid-portion of the fish's body to rise.

If the positive probe was held in contact with the tail and the negative touched to the side of the body near the head, the mid-portion of the fish again rose from the table.

Again, if the negative probe was held in contact with the center of the fish and underneath it, and the positive was touched to the center of the fish on the upper side, both ends of the fish, the head and tail, rose from the table, the motion being more pronounced than in the preceding instance.

If the positive probe was held in contact with the fish underneath and the negative touched to the center of the upper side, the mid-portion of the fish bent upward.

All of the above electrode positions are illustrated in Figure 2, the illustration in each case showing the position of the fish after any movement due to the shock had been completed.

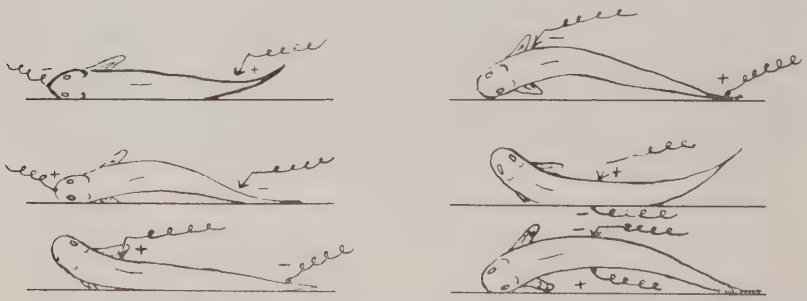

Figure 2. Motion of pithed brown trout due to direct current shock. Active electrode is indicated by arrow. Position of fish shown is after motion due to shock is completed.

Additional experiments were performed to determine the extent to which the central nervous system is involved in the reactions described. The results of each may be noted briefly.

The brain of a fish was destroyed by pithing. All reactions were unchanged.

A fish was decapitated. All reactions were unchanged.

Both head and tail of a fish were cut off and a wire pushed through the neural canal until it projected from the fish. All reactions were unchanged.

From these experiments the following conclusions may be drawn:

1. If, on a fish out of water, a direct current probe is held at one end, and the probe of opposite polarity touched to the other end, that end of the fish touched last will move.
2. If the positive probe is touched to the fish last, the motion induced is toward the probe.
3. If the negative probe is touched to the fish last, the motion induced is away from the probe.
4. The motions are independent of the brain and the spinal cord.

It may be further deduced that:

1. The nerve endings in the muscles, or the muscles themselves, are directly stimulated.
2. This stimulation causes muscular contraction which produces motion.

EXPERIMENTS WITH PITHED FISH IN WATER USING INTERMITTENT DIRECT CURRENT

Proceeding from the initial experiments on fish out of water, the effect of shock on pithed fish in water was investigated. Fish held stationary by the head were used first, followed by specimens suspended in water and free to move.

Fish Held Stationary by the Head

A wooden washtub, the bottom of which had been covered with an inch of sand, was filled with water to a depth of about 3 inches. Small electrodes were placed in the water on opposite sides of the tub. A pithed fish was placed in the tub at right angles to a line connecting the electrodes, and the fish's head was buried in the sand just deep enough to support the body and tail of the fish. The two electrodes were connected through a switch to a direct current generator (about 30 volts for 3½-inch brown trout). When the switch was closed the tail of the fish was bent violently toward the positive pole (Figure 3). Reversing the polarity and again closing the switch caused the tail to bend in the opposite direction.

The same experiment was repeated with the long axis of the fish on the imaginary line connecting the two electrodes and no consistent

effect was observed. These trials led to the conclusion that a perfect alignment of the fish with the electrodes would result in no motion. The slight and inconsistent reactions observed seemed to be due to imperfect alignment of the fish with the electrodes.

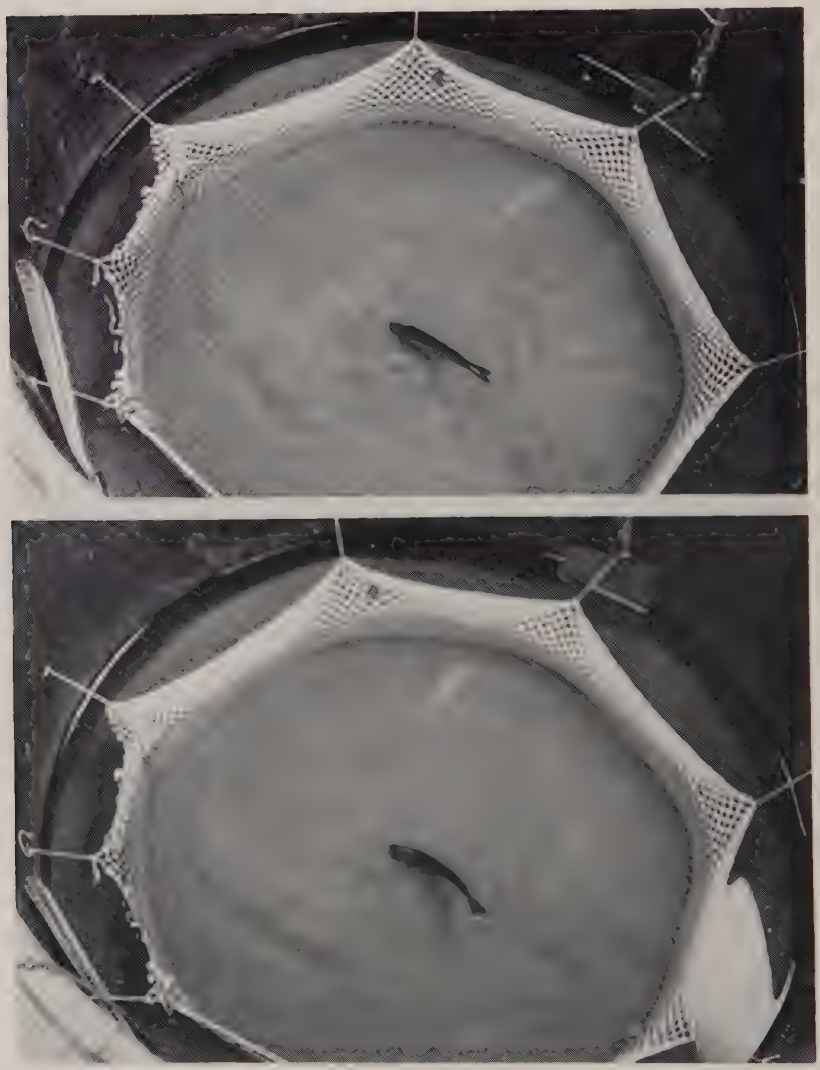

Figure 3. Tail motion of pithed brown trout in water due to direct current shock. Negative electrode at top right, positive at lower left. Upper picture is before shock; lower picture after shock.

The experiment was repeated with the long axis of the fish oriented at various angles to the line connecting the electrodes. In general the effect increased as the angle increased, up to a maximum at the right angle position.

It is well known that the lines of current-flow, in a circular field between two small electrodes, are arranged as in Figure 4. Thus, a

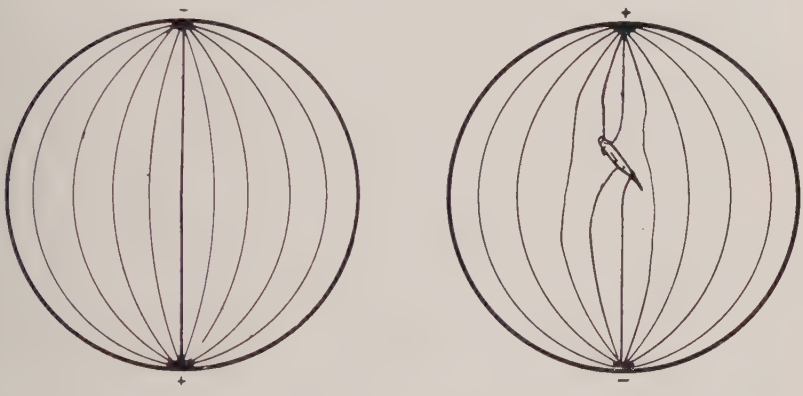

Figure 4. Lines of current-flow in a circular field: (left) normal and (right) distorted by presence of a fish

fish placed along the line connecting the two electrodes is parallel to the current-flow, while a fish at right angles to this line is at right angles to the current-flow. It follows that in the first case current will enter at one end of the fish and leave at the other end following a symmetrical course through the two sides of the fish. On the other hand, with the fish at right angles to the field, the current enters on one side and leaves on the other. Under this condition the side of the fish toward the positive electrode is made positive and the opposite side negative, and at the instant the switch is closed the fish should experience a shock and exhibit a reaction similar to that described for a fish out of water when one electrode was touched to one side and the other to the opposite side. The observed motion followed the same pattern as for the fish out of water.

For a fish at any angle other than 90 degrees to the electrical field the polarity effect is slightly more complex. As will be pointed out in another paper to appear in the next issue, the resistance of a fish is lower than that of water, at least over a range typical of New York State inland streams. Hence, in the vicinity of a fish the current

tends to converge on and pass through the fish. The current-flow when a fish is at an angle to the field is also shown in Figure 4.

In this case, where the upper electrode is positive, the effect is to make the right side of the head predominately positive and the left side of the tail negative. If the upper electrode were negative, the opposite effect would occur. In the light of these data and the experiments summarized in Figure 2, one may predict the motion which might be expected at the instant of closing the switch for all positions of the fish in the electrical field (Table 1).

Table 1. Probable Motion of a Fish Due to Direct Current Shock for Various Positions of Fish with Respect to Electrodes.

Position of fish*	Polarities produced	Resultant motion	
		Head	Tail
Pointed toward positive and to left	Right side head positive; left side tail negative	Right	Right
Pointed toward positive and to right	Left side head positive; right side tail negative	Left	Left
Pointed toward negative and to left	Right side head negative; left side tail positive	Left	Left
Pointed toward negative and to right	Left side head negative; right side tail positive	Right	Right
Pointed directly toward positive (or negative)	Entire head positive (or negative); tail opposite polarity	None	None

* Fish considered to be on direct axis between the two electrodes and to be pointed in direction of its head.

Fish Free-floating

Using the same tub and electrode arrangement as already described, a pithed fish, supported by a cork attached to its dorsal fin, was placed crosswise of the electrical field near the negative pole. The fish was unattached and free to move in any direction. The resultant motion following stimulation by a single circuit closure was recorded on movie film (Figure 5).,

A series of 15 frames depict the motion. The position of the positive electrode is indicated on the first frame; the negative was directly opposite. In the second frame the kick due to the switch closure is shown. The first motion was a violent bending of the tail to the left (toward the positive pole). This motion also caused the entire body

Figure 5. Motion of pithed fish "swimming" due to a single circuit closure. Position of positive electrode indicated in first frame, negative opposite. Movie taken at 24 frames per second.

of the fish to turn slightly to the left. In the next frame the body of the fish has turned much further to the left and its head has bent to the left with reference to the body. In succeeding frames forward motion is noted as the fish gradually straightened out and progressed toward the positive electrode.

The movie was taken at 24 frames per second and, therefore, the action shown in the 15 frames required slightly more than 0.6 second. The cork attached to the dorsal fin at the start became detached so that in the last frames the fish is on its side.

In order to check the possibility that the central nervous system might be involved in this motion, a fish was split down its back and the spine removed. The fish was then sewed together and corks attached so that it would float upright in water. This fish was caused to "swim" to the positive pole by repeated circuit closures.

Another fish was similarly opened, and the upper portion of the spine containing the neural canal was cut off. The fish was sewed together and cords attached. When it was subjected to direct current shocks in water it "swam" to the positive pole. It moved much more rapidly than the fish from which the spine was removed, probably because it had retained some of its normal muscle attachments.

From many observations of similar motions the following theory is proposed to explain the phenomenon. This explanation is somewhat oversimplified, for it is recognized that the swimming movements of a fish are often highly complex.

At the instant of circuit closure the fish receives shocks which should bend both head and tail to the left. The motion of the tail is much more rapid than that of the head, perhaps due to a difference in the stimulus but, more likely, due to a difference in the mass of the two parts. The head being large and heavy has a tendency to move sluggishly. As a result the forward motion and the turning of the body of the fish are believed to be caused by the tail. The turning of the head which is completed slightly later has a steering effect and acts as a sort of rudder on the front end of the fish.

On the basis of this explanation it is evident from Table 1 that, for any position of the fish other than one directly in line with the current-flow, the motion of the tail upon circuit closure is such as to turn the fish toward the positive electrode by rotating it in the direction which requires the lesser degree of turn to point it to that pole. It is further evident that the motion of the head is such as to always steer the fish toward the positive pole.

The source of the impetus giving forward motion requires further

explanation. If the tail is considered as a stiff appendage hinged at the caudal peduncle, then a tail motion to the right will obviously turn the fish's body to the right. However, there seems no explanation in this theory for the production of forward motion. If, on the other hand, the tail is considered as a semiflexible appendage hinged at the caudal peduncle, then, if the tail moves rapidly to the right, its distal end will bend slightly to the left during the motion. This bending back of the end of the tail will cause it to produce a forward push. As the lateral motion of the tail reaches its maximum, the distal end will straighten. The assumed positions of the fish during this motion are shown in Figure 6. Because the actual motion of the fish was too

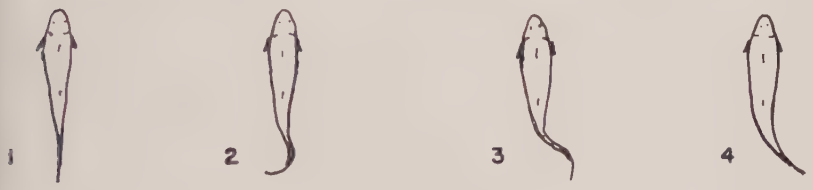

Figure 6. Assumed tail motion of a fish which has received a direct current shock. A turn to right and forward motion results.

fast to be detected by eye or by the movie, this theory of forward motion was tested on a mechanical model, which behaved as predicted.

It is believed that it is necessary to make a sharp distinction between normal swimming and the motion produced by direct current impulses. Normal swimming, as described by Young (1952) and others, is a sinuous motion involving the entire body of the fish. The motion due to an electric impulse seems to lack any sinuous quality and, although some motion of the central portion of the body is probably involved, the importance of the tail motion can be demonstrated by attaching splints along each side of the fish's body, with rubber bands, leaving only the posterior quarter of the body free to bend. Such a fish, held upright by corks on top and a lead underneath, will "swim" quite readily to the positive electrode.

Threshold Voltage

Using a pithed fish in the tub with its head supported in the sand, the circuit was repeatedly closed and opened, and before each closure the voltage was increased starting from zero. No effect was observed until a certain voltage had been reached. This voltage is termed the threshold voltage. As the voltage was further increased

the effect increased until the voltage was about 20 per cent above this threshold. Further increases of voltage did not increase the effect until a second threshold was reached as described under the next topic. The initial threshold voltages for hatchery brown trout ranging in size from 3 to 7 inches are shown by the crosses in Figure 7. The threshold voltage was not a sharp line of demarcation and was quite variable with individual fish of the same size.

EXPERIMENTS WITH PITHED FISH IN WATER USING STEADY DIRECT CURRENT

All of the tests with intermittent current were made at a voltage only slightly above the threshold for tail movement on closure. If the current was left on, the tail seemed to relax after its initial motion and slowly returned to its normal center position. However, if the voltage was progressively increased above the initial threshold, a second threshold was eventually reached at which the current, if left on, had a more lasting effect. This second threshold voltage for 3- to 7-inch brown trout is shown by the circles in Figure 7.

At voltages above this second threshold, when the switch is closed, the tail bends upon closure. The steady current then will hold it in the bent position. Considerable force must be applied to the tail to straighten it, and when straightened it will again bend. The bending due to steady current is always in the same direction as for intermittent current.

When the tail is held in the bent position due to steady current it is not under constant pull but rather a rapid and irregular series of muscular twitches. Thus the tail vibrates slightly and erratically. The pull due to steady current may persist for 30 seconds or more, and will be resumed after a rest period. Obviously were the fish free to move, it would change position rapidly and the shock would change.

The pull of steady current is like the effect of intermittent current in that it is at a maximum when the fish is crosswise of the current-flow and at a minimum when in line with current-flow. However, even when a fish is lined up with the current-flow as closely as possible, there is, nonetheless, a slight twitching. Often this twitching causes the tail to bend slightly. Once a bend is produced, the effect increases and the tail may bend to a maximum. Since this motion is slow it does not cause much movement of the fish.

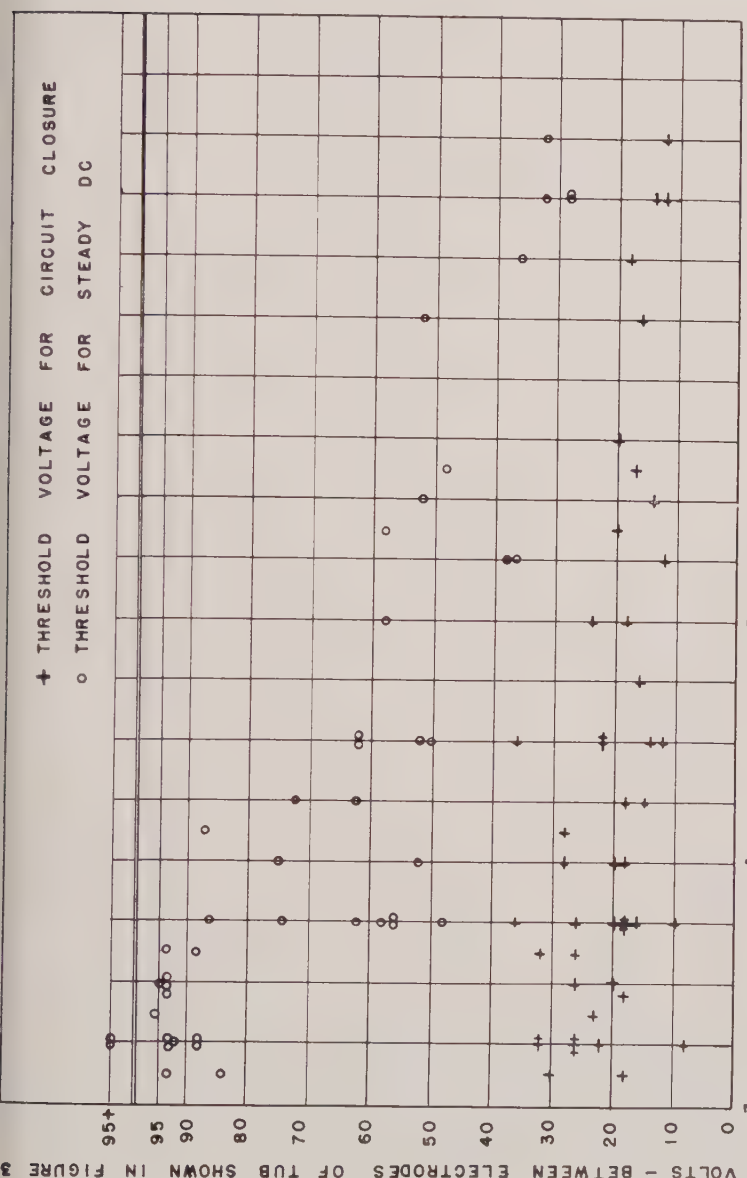

Figure 7. Threshold voltages for motion resulting from intermittent and from steady direct current shock.

Strangely, the effect of steady current is not of the same duration for live as for pithed fish. A live fish, with its head immobile, exhibits the same effect as does a pithed fish, but the effect disappears after about 5 seconds. This is apparently of little practical importance since, were the fish free, it would have moved to another position.

MOTION OF LIVE FISH IN A DIRECT CURRENT FIELD

The behavior of live fish in a direct current field is characterized by three types of reaction which will be discussed separately. These have been given the following names: voluntary motion, involuntary motion, and anesthesia. The discussion includes experimental data, deductions and theories.

Voluntary Motion

Voluntary motion of a fish, in a direct current field, is defined as motion caused by the central nervous system. Included are any normal swimming movements which the fish might perform even in the absence of the electric field. Also included are motions caused by discomfort due to the electric shock. In a direct current field it has been repeatedly noted that a fish apparently suffers discomfort at the instant the circuit is closed. This, in general, produces a rapid dashing about in no particular direction, and is almost independent of the directional effects to be described later. Somewhat similar effects may be noted on subsequent closures, but the major "voluntary motion" follows the initial circuit closing.

Involuntary Motion

Involuntary motion, as used in this paper, may be defined as that motion induced by shock independently of the central nervous system. The reactions are those which have been described for pithed fish. The primary reaction is a strong body movement at each circuit closure. A minor and negligible motion occurs when the circuit is opened. The reaction on opening the circuit is greatest (although small) if the current is interrupted quickly, and a minimum reaction is observed if the current is reduced to zero slowly.

In addition, steady current creates a directional force for any normal swimming, resisting any motion tending to turn the fish away from the positive pole and aiding any motion tending to turn the fish toward that pole.

Anesthesia

Although a fish apparently suffers no discomfort due to steady

direct current after the initial shock, irrespective of the motion of the fish, anesthesia gradually develops. Any inclination to voluntary motion disappears and response to intermittent current is lessened. The fish recovers quite rapidly when the circuit is opened, as compared to the shock of alternating current. The anesthetic effect reaches a maximum when the fish is lined up parallel to the direction of current-flow and a minimum when it is at right angles to the direction of current-flow. In fact, it has been observed that if a fish aligned with the current-flow becomes anesthetized it will, in many cases, recover if it is turned crosswise of the field. Motion will then be induced to cause it to turn back parallel to the current-flow and anesthesia again will take effect.

Resultant Motion From The Three Types of Reaction

Summing up the foregoing discussion, the motion of a fish resulting from direct electrical current is a composite result of the three types of reaction. If a fish swims in a field of steady current, it will be directed to the positive pole as long as the voluntary motion persists. If, however, it stops in the field, often no further motion will be induced and anesthesia will gradually result. Thus, with steady current, failure to migrate to the positive pole may often result unless some other stimulus causes a fish which has stopped to resume motion. It is believed, but not proved, that the shocker operators moving around in a stream as well as the water current itself may in many cases provide the necessary stimulus to a fish to cause it to resume motion.

A more reliable and powerful stimulus to motion may be provided by the use of intermittent direct current. Thus, at each circuit closure the fish is given an involuntary start which may cause swimming to continue and the migration to the positive pole to be completed. Intermittent current seems, then, to be the most effective means of providing the stimulus to assure motion to the positive pole. This stimulus fails, however, when the fish lies parallel to the direction of current-flow.

The combination of various frequencies of circuit closures with steady direct current offers an almost unlimited field for test. The investigation described here was in no sense comprehensive. Much more work may well be done in studying these effects.

The initial experiments with intermittent direct current consisted of manually opening and closing the circuit, obviously at a very slow rate. Subsequently an apparatus was constructed to open and

close the circuit mechanically. Tests were begun opening and closing the circuit at about 60 times per second and the rate of opening and closing (frequency) was gradually reduced. Using live fish no significant reactions were observed until the frequency had been reduced to about 15 per second, when movements of the type already described were noted. Further reduction of the frequency increased the effect until a frequency of one to two per second was reached, at

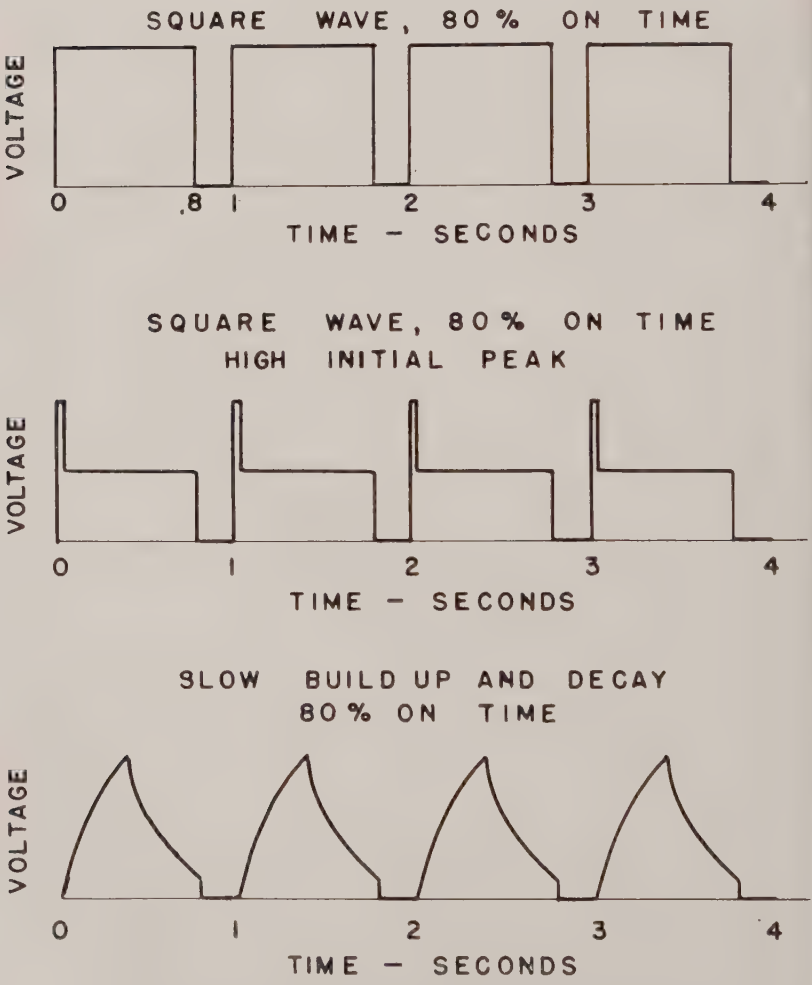

Figure 8. Intermittent direct current cycles used in tests.

which point a maximum reaction was observed. The remaining tests were conducted at a frequency of one per second.

Again using pithed fish, tests were made to determine how long the current must remain on to produce a maximum involuntary motion. A circuit was set up to produce an "on" time which, although unmeasured, was estimated from the characteristics of the circuit to be about 16 to 20 milliseconds. Maximum involuntary motion was observed. Thus, for involuntary motion, extremely short impulses are adequate.

Two other reactions, however, made necessary an increase in the "on" time, so that, eventually, the tests were based on a repeated sequence of 0.8 second on followed by 0.2 second off. An 80 per cent "on" time was required because, with a short "on" time, first, the fish was not controlled during the "off" time and moved in wrong directions, and second, anesthesia did not result. Although complete anesthesia is undesirable, a certain degree of sedation is required to minimize the effect of voluntary motion. For example, as has been pointed out, the initial voluntary motion following circuit closure is so powerful as to overbalance other effects, and no directional swimming results until a slight degree of anesthesia is produced. Somewhat later, when complete anesthesia is produced, all motion stops. Thus the migration to the positive pole must be produced in the relatively short time between partial and complete anesthesia.

The square wave, 80 per cent "on" time cycle, which was believed best is shown in Figure 8. The other two cycles shown in Figure 8 were tried but no significant improvement was noted from the use of either. It was concluded that, in stream work where the maximum voltage is limited to a specified value for safety, the square wave with 80 per cent "on" time, was preferred.

PHYSIOLOGICAL ASPECTS OF DIRECT CURRENT STIMULI

The effect of direct current shock on nerves lies in the field of physiology. The present authors, not being physiologists, can merely review some of the published findings which seem particularly applicable to this study. The following paragraphs have been abstracted from Best and Taylor (1943).

> Nerve fibers may be stimulated electrically, thermally, chemically or mechanically. Electric stimuli are convenient for testing nerve response in animals and humans since the intensity of the stimulus may easily be measured. Usually one rather large electrode is attached to the body and a second smaller electrode touched to other points on the body. The latter is termed the active electrode

since nerve stimulation, and muscular response occurs at the point touched with the small electrode. It is found that response is greater on closing the circuit, than on opening the circuit. It is also found that the response is greater when the active electrode is negative than when it is positive.

It is found that a low voltage impulse may cause no response while if, on repeated tests, the voltage is increased a threshold voltage is reached at which a definite response is caused. Higher voltages do not increase the response.

Constant current causes no reaction.

The value of the threshold voltage depends on its duration up to a limit which varies with different nerves but in many cases is of the order of three milliseconds. For any time of duration beyond this limit the threshold voltage is constant. Below the limit the shorter the duration the greater the required threshold voltage. The muscular contraction may not be completed during the impulse, but will continue until a maximum contraction is reached for any value above the threshold.

It is found that a rapid rate of voltage rise is necessary to produce a response. The usual stimulus for nerve testing is a voltage attaining its maximum within one millisecond.

Sub-threshold voltages apparently affect the nerves since several such impulses occurring at very short intervals will cause a response equal to that produced by a threshold voltage, the phenomenon being termed the "summation of inadequate stimuli".

The foregoing statements of Best and Taylor seem to apply to the findings reported here with one exception. Steady direct current produces no muscular contraction when applied to a single human or animal nerve but does have an effect on a fish, perhaps because in a fish shocked in water many nerves are stimulated simultaneously.

LITERATURE CITED

Best, C. H. and N. B. Taylor. 1943. Psysiological basis of medical practice. Williams and Wilkins Co., Baltimore: 1305-1326.

Houston, Robert B. 1949. German commercial electrical fishing device. U. S. Dept. Int. Fishery Leaflet 348.

Peterson, C. E. 1952. Electrical-fishing experiments in salt water reported successful. Commercial Fish. Review 14(10):62-64.

Rayner, H. J. 1949. Direct current as aid to the fishery worker. Prog. Fish-Cult. 11(3):169-170.

———— 1950. Electrodes used in electrofishing. Prog. Fish-Cult. 12(1):42-43.

Young, J. Z. 1952. The life of vertebrates. Oxford Press, New York: 130-131.

TWO BACK-PACK FISH SHOCKERS[1]

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ABSTRACT

The considerations involved in the design of a back-pack fish shocker are discussed.

The circuits and electrical performance data are presented for two such units. Each weighs about 30 pounds including carrying case. The first is adapted for use only in soft and moderately hard water; the second will operate quite effectively in waters with resistivities of 1,500 to 28,000 ohms per centimeter cube.

In designing a back-pack shocker the theoretical objective is to produce the same amount of electric power that is ordinarily obtained from a generator, and at the same time to restrict the size and weight so that the unit may be built into a reasonable one-man pack. In practice the design must involve a number of compromises.

CONSIDERATIONS IN DESIGN

The designs given in this paper were based on the following specifications:

1. The power supply was to be used on two paddle-type electrodes each 6 inches square. The two electrodes were to be handled by the man carrying the pack, and, therefore, might be as much as 6 feet apart, or be brought very close together. The restriction was placed on the design that, if the electrodes were brought closer than 6 inches from each other, a blown fuse would be expected.

2. It was proposed to maintain the highest possible voltage between electrodes up to a maximum of 220 volts.

3. The power unit must permit operation over the range of water of New York State streams. These streams, with a few possible exceptions, have a range of water resistivity of from 1,500 to 28,000 ohms per centimeter cube.[2]

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-1-R.

[2] The unit of resistivity in ohms per centimeter cube is the resistance of a cube of material 1 centimeter on a side in which current enters through one face and leaves at the opposite face.

4. The unit was to be designed to produce alternating current, with a circuit also provided to convert the output to direct current.

5. A weight limit of 30 pounds was assumed.

In order to evaluate the power requirements, the current which would be drawn by the two 6 x 6 inch electrodes for various spacings with an electrode to electrode voltage of 220 volts is shown in Figure 1.

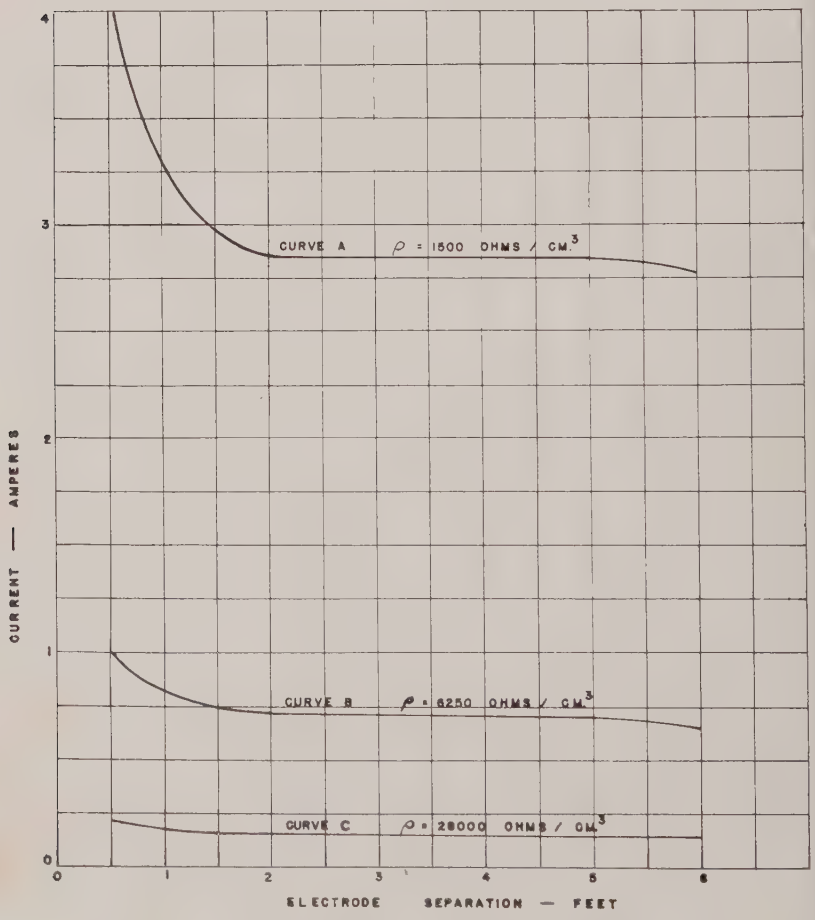

Figure 1. Current drawn by two 6 x 6 inch electrodes at three degrees of resistivity for various spacings at a depth of 1 foot below the surface in 3 feet of water in large pool. Electrode to electrode voltage—220 volts.

The curves are for water resistivities of 1,500, 6,250, and 28,000 ohms per centimeter cube. In obtaining the data the electrodes were held 1 foot under the water surface in about 3 feet of water. The stream width was about 10 feet and the electrodes were near the middle. Curve B depicts actual data. Curves A and C are calculated, based on the difference in the resistivities.

Two units have been designed. The electrical circuits are given in Figures 2 and 3. The first, built in 1950, has received extensive field tests and because of its obvious limitations, particularly in hard water, was never publicized. Each unit is based on a fundamentally simple circuit. Power is obtained from a 6-volt storage battery. This direct current power is changed to low voltage alternating current by the use of a vibrator, and the low voltage is then changed to higher voltage by a transformer. The transformer output is connected to the electrodes.

The components of the first shocker were selected to make the maximum output equal a reasonable drain on the storage battery used. This battery could deliver 17 amperes which at 6 volts equals 102 volt-amperes (volts x amperes). If this output could be converted to 220 volts, without loss and with a corresponding decrease in permissible current, the maximum output current would be 102 divided by 220 or 0.46 amperes. Referring to Curve C in Figure 1, it appears that 0.46 amperes is adequate for all electrode separations in soft water. On the other hand the current required for harder water, Curves A and B, is far larger than could be produced by such a unit.

A shocker would have very limited usefulness if restricted only to the very soft waters. For this reason the maximum voltage output for the first design was reduced to 150 volts. This reduced the current drawn for any electrode spacing to 68 per cent of its value at 220 volts. In addition the circuit used was such as to lack "stiffness", which means merely that as the current load increases the voltage drops rapidly. The output voltage current characteristic of the first shocker is shown by the lower curve in Figure 4. The radial lines from the origin represent resistances corresponding to the electrode separations shown. The intersection of one of these lines with the curve for the shocker output represents the voltage and current that the shocker would deliver under that load. The dotted lines indicate, for example, that in water having a resistivity of 28,000 ohms per centimeter cube and with a paddle separation of 6 inches, the

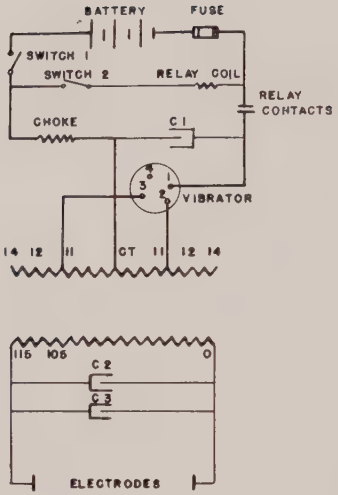

Figure 2. Circuit used for first back-pack shocker.

Parts used in first shocker

Battery:	6 volt motorcycle battery, Willard MFW-5-3
Fuse:	Type 3 AG—12 amp.
Switch #1:	Open knife switch mounted on outside of power unit where readily accessible
Switch #2:	Mounted on paddle handle (Test to be sure relay will not close contacts with switch open but immersed in water)
Relay:	6 volt automobile horn relay
Choke:	Mallory A42204-1
Condenser C1:	0.5 MFD—50 V.D.C., Mallory RF481
Condensers C2 & 3:	0.1 MFD—1600 V.D.C., Aerovox type 2584
Vibrator:	Mallory 825C
Vibrator socket:	Mallory A-15211-1
Transformer:	UTC type S63

Parts used in second shocker

Battery:	6 volt, Willard ER-32-6
Fuse:	40 amp.
Switch #1:	Open knife switch mounted on outside of power unit where readily accessible (SPST)
Switch #2:	Mounted on paddle handle (Test to be sure relay will not close contacts with switch open but immersed in water)
Relay:	6 volt automobile horn relay
Condensers C1, 2, 3, 4, 5, 6 & 7	0.5 MFD—200 V.D.C., Radiart C-562
Chokes (2):	Radiart part T-1393
Vibrator:	Radiart type 2639
Vibrator sockets:	Two for above vibrator
Transformers T1 & 2:	Triad F23U
Condensers C8 & 9:	0.75 MFD—1600 V.D.C. (each condenser may be made up of five 0.15 MFD—1600 V.D.C. condensers in parallel—Aerovox type 2584)
Switch #3:	Open knife switch (DPDT)
Rectifier:	Full-wave selenium rectifier (see text)

The above parts are those actually used. Equivalent parts of other manufacturers may be substituted.

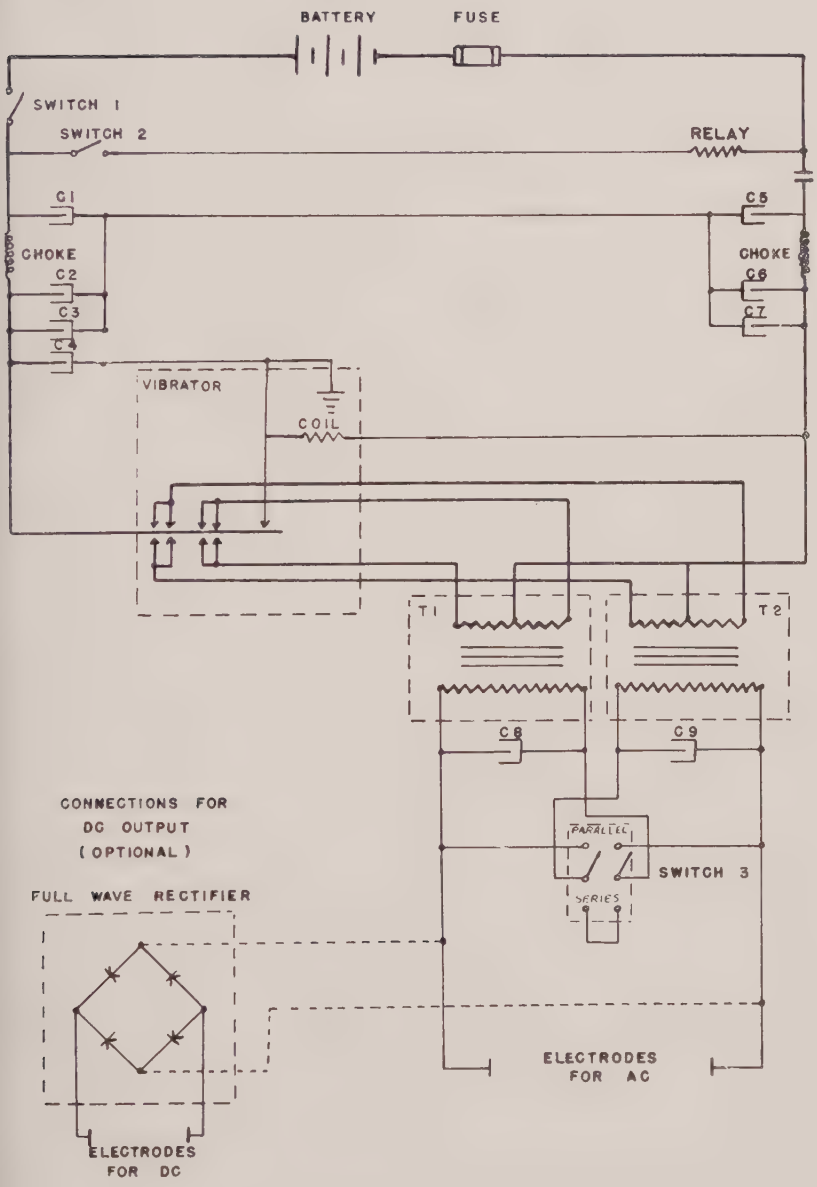

Figure 3. Circuit used for second back-pack shocker.

first shocker would produce 118 volts and the current would be 0.13 amperes.

As the current load increases the voltage rapidly drops. This fact makes it possible to use the first unit in water having a resistivity

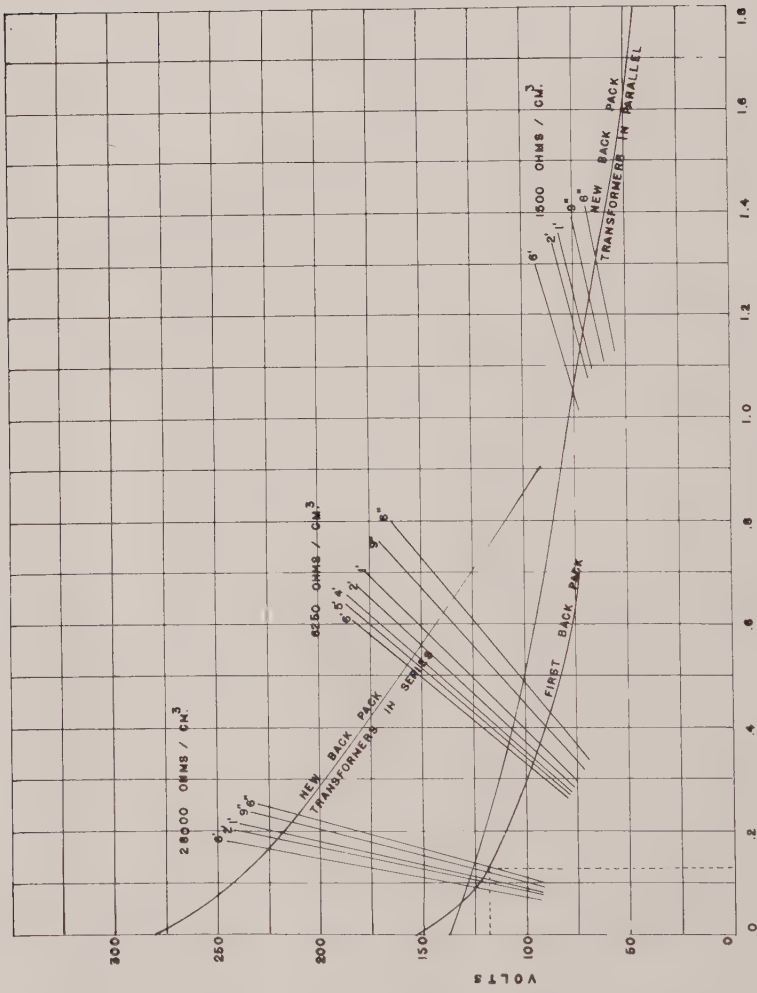

Figure 4. Voltage and current output of two back-pack units.

of 6,250 ohms per centimeter cube without exceeding the maximum allowable current which is 0.7 amperes. However, the harder the water, the less the voltage that is available, and consequently the effectiveness of the unit is reduced. For the first design the voltage is so reduced in water of 6,250 ohms per centimeter cube as to make use of the unit quite exasperating. Too many fish are rolled over but escape because they are not effectively stunned. In soft water or in very small streams the unit is fairly satisfactory.

In the second design, an attempt was made to double the output without increasing the weight. A plastic type battery was obtained having a very high rating and the same weight as the motorcycle battery used in the first unit. The vibrator and transformers of the second unit likewise have greatly increased ratings and their combined weight approximately equals that of those in the first unit. The maximum allowable current load is about 0.9 ampere. This unit is very satisfactory in soft and moderately hard water (28,000 to 6,250 ohms per centimeter cube). In water of resistivity equal to 1,500 ohms per centimeter cube its current rating would be exceeded. Therefore, a switch is provided to put the two output transformers in parallel instead of series, reducing the voltage by one-half but increasing the current rating to 1.8 amperes. This output is shown in the middle curve of Figure 4. The voltage available in very hard water is only about 75 volts compared to 150 volts with the transformers in series in moderately hard water and 220 volts in soft water. A test of the unit in the outlet of the Caledonia Fish Hatchery (1,500 ohms per centimeter cube) indicated that 75 volts is adequate in this water.

CONSTRUCTION AND OPERATIONAL SUGGESTIONS

Figure 5 shows the first back-pack unit. The arrangement of the parts and the over-all dimensions can be varied but the unit should be kept as compact as possible.

The arrangement of the parts should be such that the wires carrying the battery output current are as short as possible. The heavy current wires (from the battery to the transformers and vibrator, as well as between the latter) are indicated in the wiring diagrams as heavier lines. The wire size for these should not be smaller than No. 12.

The parts of the shocker should be enclosed in a box which is reasonably waterproof because many of the parts would be damaged by immersion in water.

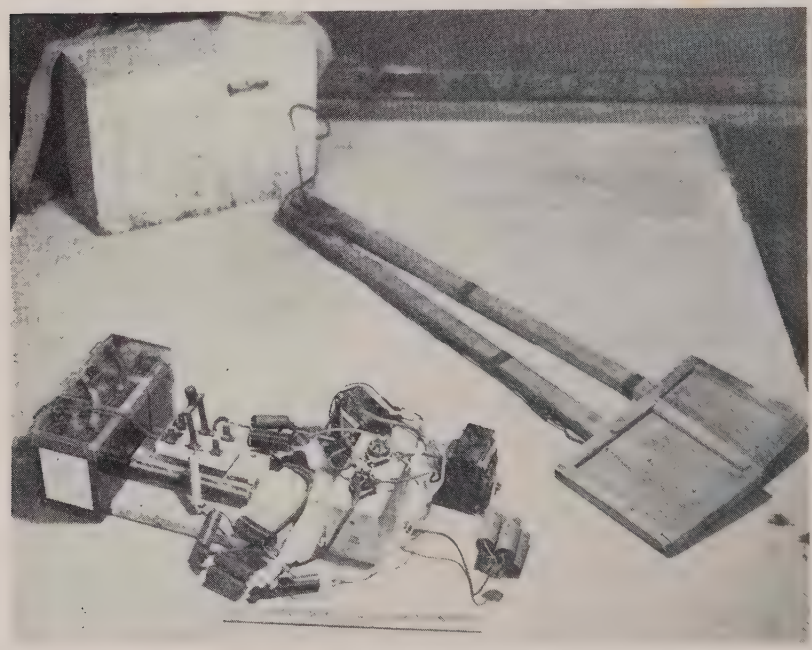

Figure 5. Components of second back-pack shocker assembled for test (foreground); first back-pack unit (left background); electrodes used for both units (right background).

The plastic type battery used in the second design is quite fragile and should be so mounted that it cannot slide about.

The switch operating the relay to turn power off and on is mounted on one electrode handle. The unit constructed by the authors uses an open switch made from a piece of spring steel which can be pressed down against a contact by the hand of the operator holding the electrode. The shock hazard on this circuit is negligible since it is a 6-volt circuit. The switch should be tested to insure that it will open the relay circuit even though it is immersed in water.

A second switch is provided in the battery output circuit as a safety measure. This is an open knife switch and should be mounted on the outside of the back-pack unit, where it will be readily accessible to a person accompanying the operator in case the operator falls. *The back-pack unit should never be used by one person alone.*

The batteries will require frequent recharging. To extend the amount of use before charging is necessary, the power should be turned off whenever possible. In order to approximate the rate of

General view of two-man crew using back-pack shocker, one carrying pack unit and operating electrodes and the other carrying pail and net for capturing the fish.

A brown trout, between electrodes, immobilized by electric shock.

battery discharge a test was made with a load of 1.2 amperes (transformers in parallel). A cycle of 30 seconds on and 30 seconds off was repeated for 1 hour. At the end of the test the battery was only partially discharged, and it was estimated that it would have operated for at least another half-hour.

If it is desired to convert the shocker output to direct current, a bridge-type full-wave selenium rectifier is recommended. Since these units are quite expensive for the higher current ratings it is suggested that a decision be made as to the hardest water in which the unit is to be used before the rectifier is purchased. The current rating of the rectifier should be approximately 80 per cent of the current shown for alternating current in Figure 4 for water of the lowest resistivity in which the unit is to be used.

The following are the weight and cost data of the two shocker units, exclusive of rectifiers. The prices are based on the wholesale prices of the individual components in 1952.

	Weight of electrical equipment	*Approximate price of parts*
First unit	24 lbs.	$40.00
Second unit	25 lbs.	$75.00

In conclusion, it should be pointed out that many commercial units are produced having much the same circuit as that used in the back-pack units. However, none was known to the authors that had the desired output curve. It is hoped that some manufacturer of similar equipment may interest himself in the design of a unit having suitable characteristics for shocker work. Several improvements in the devices used would be obvious since one of the most difficult phases of assemblying such a circuit is that of securing commercially available items which approach the desired specifications.

The authors and the New York State Conservation Department assume no patent liability for users of the circuits described.

STUDIES ON SURVIVAL OF THREE STRAINS OF MALLARD DUCKLINGS IN NEW YORK STATE[1]

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ABSTRACT

During the summer of 1952, the survival of three strains of mallards was studied in an evaluation of this species for stocking purposes. A total of 811 mallard ducklings was released in New York State at an age of approximately 5 weeks. Most of them were liberated on small (1 to 12 acres), man-made marshes, although some were placed on larger natural or developed areas for comparative purposes. Survival to the age of flying was determined by intensive survey, observations being facilitated by the use of colored leg bands and neck markers.

No significant differences in survival were noted among the strains, although the "Canadians" reached flying age sooner and were warier. Variations in survival to flying age of all strains could be correlated with fluctuating water levels and availability of emergent escape cover. Differences in date of release, type of area (natural or man-made), elevation of the area and density of stocking had no obvious effects upon survival. Known predation on ducklings amounted to 5.1 per cent with raccoons, foxes, owls, and turtles being most important. Mammalian predation was heaviest where water levels dropped most. Survival to flight age averaged about 61 per cent on all the areas used and about 72 per cent on those where all three strains were released together.

Since the early 1930's, mallard ducks have been propagated on New York State game farms and liberated annually in an effort to establish this species more extensively as a breeding resident. Considerable selection of breeding stock has been practiced toward the end of producing a mallard as similar to the wild strain as possible. This has resulted in what is known as the "New York" mallard.

There have been some questions as to whether and by what means the survival value of the New York mallard could be improved and especially whether this propagated bird is endowed with capability of survival upon liberation comparable to that of the truly wild strain. An attempt to answer the latter was made possible by the procurement of wild Canadian mallard stock through the generous cooperation of the Canadian Government and the Delta Waterfowl Research Station in Manitoba.

PROCEDURE

The three strains studied were as follows: (1) the game farm stock presently used, known as "New York" mallards; (2) those pro-

[1] The author wishes to acknowledge the help and suggestions given by the following during the field studies: Robert V. Folker, John A. Hammond and Bruce T. Wilkins, students at Cornell University; William C. Dilger, Assistant at Cornell University; and Richard A. Ryan, Instructor at Hobart College.

vided by the Delta Station as eggs or day-old ducklings, known as "Canadians"; and (3) the progeny of New York and Canadian breeders, known as "crosses". Hatching, except as indicated, and all rearing was done at the Delmar State Game Farm under P-R Project 68-R (Waterfowl Propagation Research), while the liberations and survival studies were made as part of P-R Project 39-R (Waterfowl Management Research).

A total of 811 mallard ducklings was released in June and July, 1952. All of the birds were approximately 5 weeks of age at the time of release, since this age had been found by earlier work (Benson, 1939) to provide the greatest return in terms of money spent.

Most of the releases were made on very small marshes and water areas, principally the farm wildlife marshes constructed under P-R Project 48-D (Improvement of Wildlife Habitat on State and Private Lands) where the average size of those selected was about 4.2 acres. This was done for two main reasons: (1) ease of observation and (2) to attempt to establish and study populations over as wide an area of the State as possible. It was realized that this might not produce results as representative of the State as a whole as could be expected from more extensive, better quality areas, but it was thought that better opportunity for more thorough observations made up for this deficiency. A few natural marshes were used, however, for certain comparisons. Altogether, 44 water areas were used as release sites throughout the State. Of these, 38 were selected small marshes established under Project 48-D from 1949 to 1951 and six were natural marsh or swamp areas, generally of larger size. Three of the latter were beaver flows. The number released per area varied from 10 to 90, with the larger numbers assigned to the larger natural areas where equal numbers of the three strains could be contrasted.

The ducklings were released in four lots as they arrived at 5 weeks of age, from June 25 to July 23. As they were caught at the rearing pond they were sexed and banded with both Fish and Wildlife Service bands and colored plastic bands, the latter coded according to their scheduled release site. In addition, where mallards of two or more strains were to be released on any one area, the birds were distinctively marked with colored plastic tags after the manner of Wint (1951) for quail and modified by the use of stainless steel pins as described by Gullion (1951) for coot. The use and success of these colored plastic markers on ducklings will not be discussed in this paper, though it may be said at this time that they generally enabled the duckling groups to be followed successfully to flying age.

All ducklings were boxed 10 or 15 to a container, depending upon the number to be released, and most of them were liberated the same day. Although many were transported by truck hundreds of miles during extremely hot weather, only four of the 815 birds crated died en route.

During the period from liberation until after the time the birds were flying, each area except a few of the larger sites was covered routinely once a week, and generally more often, by game technicians. Observations were usually made in early morning and late afternoon or evening. The ponds or marshes to be studied had previously been selected in strategic regions throughout the State, and each technician was so located that he could easily cover his six to eight areas. Detailed instructions were given as to the purpose of the study and the methods to be employed. Form sheets were provided to facilitate the recording of comparable data.

FINDINGS

Of the 811 ducklings released, 336 were of the New York strain, 254 were pure Canadian stock, and 221 were crosses. The observed survival of these three groups up to the age of flying is shown in Table 1, not considering any of the various factors which may have affected such survival.

TABLE 1. SURVIVAL OF MALLARD DUCKLINGS OF THREE STRAINS LIBERATED EXPERIMENTALLY IN NEW YORK STATE IN 1952

Strain	Total number liberated	Number liberated on areas followed routinely to flying age of the birds	Survival at flying age	
			Number observed	Per cent
New York	336	307	170	55.4
N. Y. x Canadian	221	195	131	67.2
Canadian	254	220	141	64.1
Total	811	722	442	61.2

While it would appear at first glance that the Canadians and crosses survived much better than the New York strain, this could largely be explained by the fact that most of the birds released in June were New York ducklings placed on areas of generally lesser importance and poorer quality. There was, however, no statistically significant difference in survival between the three strains. This is shown better when a survival comparison is made using only the

areas upon which all three strains were released together (Table 2). Here, the success of the three strains was practically identical. The degree of survival, also, must be considered as very good, especially since the ducklings were without the protection afforded wild ducklings by a watchful hen.

Table 2. Survival of Mallard Ducklings of Three Strains Where Liberated Together on the Same Area

Strain	Number liberated	Survival at flying age	
		Number observed	Per cent
New York	115	81	70.4
N. Y. x Canadian	115	86	74.8
Canadian	115	82	71.3
Total	345	249	72.2

However, if one bit of evidence found this year is representative, namely, the age at which the ducklings were observed to fly, then it must be concluded that the Canadian strain has an obvious advantage. Their observed survival was as good as that of the others, and they were seen to take to the air a week or 10 days sooner than the other groups (Table 3). The differences in age at which the three mallard strains were seen to begin flying are perhaps shown better in Table 4 which gives the percentages for those flying before and after the arbitrary age of 9 weeks.

Table 3. Percentages of Mallard Ducklings of Three Strains Observed to Reach Flying Age at Various Ages

Strain	Age in weeks										
	7	7½	8	8½	9	9½	10	10½	11	11½	12
New York	..	..	12.8	9.6	19.3	3.9	38.8	3.9	7.8	..	3.9
N. Y. x Canadian	..	..	5.4	13.6	48.6	10.8	16.2	..	5.4	..	..
Canadian	4.5	4.5	22.7	9.3	36.4	4.5	13.6	4.5	..	..	..

Table 4. Percentages of Mallard Ducklings of Three Strains Which Apparently Began Flying Before and After 9 Weeks of Age

Strain	Began flying on or before the ninth week	Began flying after the ninth week
New York	42	58
N. Y. x Canadian	68	32
Canadian	77	23

Besides the obvious comparisons made of the three strains directly as regards survival to the age of flying, various other correlations were attempted on the basis of the following differences:

1. Region of the State where liberated
2. Type of area (natural or man-made)
3. Density of released birds per acre
4. Date of release
5. Elevation of release sites
6. Survival according to sex
7. Survival according to type of marker and number of bands
8. Amount of emergent cover available

Regional differences as to location, climate, soils, topography, etc., were reflected to some degree in the survival of the ducklings to flying age, although it was very difficult to correlate these data. During the summer of 1952 the drought in certain sections of the State caused many normally wet areas to go dry, and generally better survival was noted in regions having the greatest precipitation. There were local exceptions to this, however, where water levels were maintained due to springs or to a type of watershed providing larger or more constant runoff.

Where opportunities were available for contrasting man-made and natural areas it was found that survival on them was very similar. It would appear, therefore, that on selected man-made areas duckling survival might be even higher than on average natural marshes once maximum development of their vegetational conditions has been achieved. This is assuming, of course, that development of these man-made areas would not account for a parallel increase in predation or other mortality factors which perhaps were exerting a subnormal influence during this study. These statements are based on the fact that all the small, man-made marshes tested here were very recent developments, none more than 4 years old, and on the premise that under proper management their vegetational succession, water levels, etc., can be manipulated to improve substantially their quality as waterfowl habitat.

Survival according to the density at which the ducklings were stocked, from fewer than one to nearly 10 per acre, indicated no correlations. No downward trend in success could be noted from the areas more thinly stocked to those more heavily stocked. Ap-

parently the limit to which stocking could have been carried on many of these areas was not reached.

No differences could be seen in the survival of groups liberated at different dates, although this would be a point to consider where releases are to be made over a longer period. Development of vegetation would be a prime factor to consider in scheduling releases, and probably no birds should be liberated before the emergent plants afford a good amount of escape cover. Likewise, few releases should probably be scheduled for late summer in this State when low water levels are common. Apparently the period of June 25 to July 23, when the birds were released for this study, was close to the optimum for duckling success in New York in 1952.

The mere differences in elevation of the many areas did not obviously result in varying survival of the ducklings, although elevation and stream gradient might have been expected to influence the abundance of blackflies and, therefore, *Leucocytozoon* disease. With no apparent mortality from this cause in 1952, explanations might be that none of the sites were located in the main centers of blackfly distribution, that blackflies were not especially numerous in 1952, or that the ducklings were released at an age when they were probably less vulnerable to fatal infection and at a date when blackfly abundance was waning.

Survival of the ducklings could not be correlated to any degree with the numbers of colored bands worn or with the color of the neck marker. Unmarked ducklings (except for the Fish and Wildlife Service band) suffered similar mortality. This would also indicate that there was little or no mortality caused by the marking operation.

It was not practicable to calculate exactly the amount of escape cover (emergent cover that is easily negotiated by swimming ducklings is more descriptive) on each area. The sites were, however, rated as to whether this cover was sparse, fair, moderate, or abundant in amount. No attempt was made to consider "quality" of cover plants at this time. The survival to flying age observed for the three mallard strains on the basis of the amount of cover available is given in Table 5.

Apparently there was a direct relationship between the amount of cover available and the success to flying age of mallard ducklings liberated therein. It was noted, perhaps surprisingly, that the composition of this cover seemed to make little difference; spirea and willow provided as good survival as did bulrush and cattail as long as they remained equally negotiable. This, obviously, was the chief reason for the losses on areas which become deficient in water, since

TABLE 5. PERCENTAGE SURVIVAL OF MALLARD DUCKLINGS OF THREE STRAINS ACCORDING TO AMOUNT OF NEGOTIABLE EMERGENT COVER AVAILABLE

Strain	Cover			
	Sparse	Fair	Moderate	Abundant
New York	23.3	63.3	65.3	75.5
N. Y. x Canadian	50.0	60.0	70.0	85.5
Canadian	30.0	63.3	64.4	70.0
Average	27.5	62.5	66.7	77.9

it was not water loss alone which increased the vulnerability of the birds to predation but the fact that falling water levels made the escape cover untenable.

Predation accounted for a known mortality of 5.1 per cent of the 722 mallards liberated on areas covered routinely to flying age, although 243 other birds were unaccounted for and possibly suffered a similar fate. With the intensive manner in which these areas were covered, it was usually not difficult to determine the cause of death of any kill found, and it was of interest to learn the predators responsible for most mortality. Table 6 shows the known mortality among the ducklings according to predator and strain.

TABLE 6. DEGREE OF KNOWN MORTALITY AMONG THREE STRAINS OF MALLARD DUCKLINGS

Strain	Species of predator									Total	Per cent of ducklings liberated*
	Raccoon	Fox	Owl	Turtle	Hawk	Dog	Mink	Skunk	Unknown		
New York	8	4	..	..	1	1	..	..	..	14	4.6
N. Y. x Canadian	5	..	3	1	..	..	..	1	2	12	6.2
Canadian	1	4	..	..	..	..	..	..	3	8	3.6
Unid. mallard	1	..	..	1	..	..	1	..	..	3	....
Total	15	8	3	2	1	1	1	1	5	37	5.1

* Applies to areas followed routinely to flying age of the birds (see Table 1).

Of the 37 predator kills found of these mallard ducklings, 21 could be differentiated as to strain and sex for survival comparisons. Six of the kills were male birds and 15 were females, an indication that possibly the latter were more vulnerable. This condition existed

among all three strains, although the samples per strain were very small. Little difference in susceptibility to predation among the strains could be seen (Table 6).

Raccoons and foxes preyed heavily on the ducklings in only one region, although their activities were noticed to some extent in all. The region about Batavia, the one hardest hit by the severe drought, suffered extremely low water levels on practically all areas at the lower elevations, and raccoons especially were seen to take quick advantage of this. Evidence of snapping turtle damage was not extensive, though from the nature of their habits it was not expected to be since ducklings are often completely devoured under water. Mortality from this source may actually have been much heavier, accounting for many of the missing birds. No statistical difference could be shown as to predation among the three strains, although a higher percentage of the ducklings wearing the most visible markers (yellow best, red next, blue poorest) were known to have been preyed upon.

DISCUSSION

In considering the observed survival of the three duckling groups in 1952, certain important points should be remembered. The fact that the study was carried on by eight technicians in widely separated regions of the State might be construed as introducing too many variable factors for reliable results. Also, the fact that a greater number of areas was available for selection in some regions than in others may have introduced some bias. However, since all the areas used were selected by one man and all field technicians used similar methods, these defects would tend to cancel out. In addition, in evaluating the data collected, more reliability is credited to records from those areas where all three strains were studied together.

If the fact that the Canadian strain mallards began flying from a week to 10 days sooner than the others represents a distinct characteristic of this type of stock, then this strain would certainly be the best to use in the establishment of the species. The survival experienced by them was identical to that of the other groups this year, and ordinarily the early flight age would indicate a somewhat better chance for survival. This would seem to be true especially since these ducklings were also seen to be warier and to take more naturally to emergent cover.

The most obvious effects on survival, irrespective of strain, were produced by fluctuations in water level and by the amount of result-

ing escape cover. Low water levels along with a deficiency of emergent cover easily negotiable by swimming ducklings provided a poor combination, while high, stable water levels and extensive stands of available emergent vegetation gave excellent conditions for survival. The region which suffered the most extreme drought also lost most heavily through predation.

Other factors which had been thought of as possibly having some effect upon duckling survival, such as the kinds of plants affording emergent cover, date of release, type of area (man-made or natural), elevation of the area, density of released birds per acre, and number and color of markers, had no measurable influence on the birds' success, at least under the limitations of this experiment.

CONCLUSIONS

The primary conclusions to be drawn from this study of the survival of three strains of mallard ducklings to the age of flying are that there was no apparent superiority of any strain, although the Canadians were potentially more promising, and that survival (and conversely, mortality caused by predation) could be correlated with fluctuating water levels and the amount of usable emergent escape cover. Survival to flight age averaged about 61 per cent for all areas and about 72 per cent for those where the three strains were studied together.

LITERATURE CITED

BENSON, DIRCK. 1939. Survival studies of mallards liberated in New York State. Trans. 4th N. A. Wildl. Conf.: 411-415.

GULLION, GORDON. 1951. A marker for waterfowl. Jour. Wildl. Mgt. 15 (2): 222-223.

WINT, GEORGE B. 1951. Improved method for marking game birds for identification in the field. Okla. A. & M. Coll. Bull., Biol. Ser. No. 3.

LETHAL OXYGEN CONCENTRATIONS FOR TROUT AND SMALLMOUTH BASS

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ABSTRACT

Curves for the mean oxygen concentrations lethal to fish over short exposure periods have been constructed for brook, brown, and rainbow trout and smallmouth bass. Equations are formulated to fit the straight-line curve obtained on semi-logarithmic paper. Lethal oxygen concentrations are determined at several temperatures by a procedure that involves the gradual reduction of oxygen by fish respiration in a sealed container to complete loss of equilibrium used as an end-point. The highest and lowest concentrations producing such an effect are noted for each temperature. It is not suggested the data obtained by this experimental procedure represent points above which fish can be maintained indefinitely, nor that slow and gradual acclimatization will not result in shifting the mean lethal level, but curves derived are believed to represent the lethal concentrations for certain hatchery trout and, reasonably well, fish under natural stream conditions. It is claimed the experimental procedure closely approximates the rapid decrease in oxygen in streams that is produced by intermittent discharges of organic wastes, and a comparison with conditions in one such polluted stream is made.

In the enforcement of that section of the Conservation Law dealing with pollution affecting fish life, the Conservation Department has been forced to determine experimentally the oxygen concentrations which can be considered as lethal to certain species of fish at normal temperatures in State waters. Over a number of years these data have been compiled for brook trout, *Salvelinus fontinalis* Mitchill; brown trout, *Salmo trutta* Linnaeus; rainbow trout, *Salmo gairdnerii* Richardson, and smallmouth bass, *Micropterus dolomieu* Lacepede.

The criterion arbitrarily chosen as an end-point was that oxygen concentration at which the fish suffered complete loss of equilibrium and rested motionless on its side in the container, hereafter called turnover. A close correlation betwen this end-point and the asphyxiation point was evident when it was often found impossible to revive the fish even though removed immediately to well-oxygenated water at the same temperature. It is held that the oxygen concentrations producing this end-point will be lethal to the fish within a short time if the level can be maintained. Therefore, these are considered as lethal concentrations throughout this paper.

Fish are known to withstand temporarily concentrations of toxic chemicals and harmful conditions at levels considerably above that which would be lethal with an extended exposure. Reduced oxygen concentration is included in this category. The curves for lethal oxygen concentrations presented in this paper are not intended to represent datum points above which fish can live indefinitely. They were constructed and the particular experimental method chosen in an attempt to duplicate as closely as possible the relatively rapid fluctuation in oxygen found in streams subject to heavy periodic discharge of organic wastes that require oxygen for stabilization and to derive an index that can be used to establish lethal oxygen concentrations in such streams. It has been possible to verify the approximate accuracy of the data for brown trout by field observation on such a polluted stream.

After the turnover of each fish the oxygen concentration was determined individually in order that the spread resulting from individual variation could be evaluated. The mean of these oxygen concentrations, obtained at several different temperatures, was computed and is presented in tables and graphs. Since the asphyxiation of approximately 50 per cent of the fish occurs before reaching the mean in a normally distributed population, a significant fish mortality will be evident before the oxygen falls to this level. The first appearance of a fish kill in a stream is determined by those individuals, or species, that require the greatest quantity of oxygen for existence, not by those whose requirements are average. The data covering the range of individual variation are shown as vertical bars upon the graphs.

Although pH and carbon dioxide were recorded in most of the experiments, no correlation could be found in the variation of the pH within the range covered, and the carbon dioxide stayed well below the level reported to have an effect (Hart, 1945; Fry, Black and Black, 1947; Fry, 1951), so neither is reported here.

In all species studied, within the temperature ranges covered, the mean lethal oxygen concentrations plotted on the logarithmic scale against the temperatures on the arithmetic scale appear to form a straight line on semi-logarithmic graph paper. Standard deviations and standard errors of the mean have also been calculated. Equations for the curves have been formulated.

Many papers have been written on some phase of the relation of oxygen and other natural factors to fish existence, but only a few have been found to have direct bearing on the studies reported here. Ref-

erence to some of these will be made in discussion of the experimental work on the individual species. Fry and his co-workers (1947, 1948, 1951) have shown the significance of the effect of temperature acclimatization over extended periods of time on the oxygen concentrations lethal to fish and Fry (1951) quotes other authors on acclimatization to high and low oxygen levels and the effect upon the oxygen concentrations found lethal. These studies appear to establish the range of physiological adaption possible in the fish and the ultimate maximum and minimum figures for low oxygen tolerance. However, the data derived by their methods do not seem readily transferable to fish in natural waters subject to considerable temperature and oxygen fluctuations.

In the sections on trout in this paper, the use of basic data derived from hatchery stocks is considered justified since conditions permitting stocking of these fish without mortality ascribable to unsatisfactory oxygen concentrations should be present in all trout waters. For rainbow trout a comparison curve on wild fish taken from an unpolluted stream is also presented. The smallmouth bass data deal with two separate stocks of wild fish, one from an unpolluted lake, the other from a natural stream without a significant amount of pollution. It was not possible at this time to present a curve on hatchery-reared fish.

EXPERIMENTAL PROCEDURE

Glass jars were drilled to receive pieces of rubber-gasketed, glass tubing to which a piece of rubber tubing bearing a pinch or screw clamp could be attached. Sizes used varied from 1 pint to 2 quarts depending upon the size of fish used and the temperature to which it was exposed. The jars were completely filled with water of a determined oxygen and carbon dioxide content, methyl orange alkalinity, and pH. No phenolphthalein alkalinity was present in any water used. When the jar was filled, a fish was inserted, the cover clamped, and pinch or screw clamps applied to seal the container. The fish was then placed under observation in a constant temperature bath and permitted to reduce the oxygen by respiration until the end-point was reached.

Immediately, sample bottles were filled by means of a tube reaching to the bottom of the bottle and were permitted to overflow for a short time. The fish was then removed to a container of water at the same temperature with a satisfactory oxygen content. Recovery or death of the fish was noted as was the time of starting and ending of the experiment. Assistance in recovery was often given the fish

by drawing it backward and forward in the water in order to bring more aerated water in contact with the gill surface.

Oxygen was determined by the permanganate modification of the Winkler method for both brook trout and brown trout. For the other species it was determined by an iodized-alkaline-iodide sample blank procedure similar to that recommended by Ellis, Westfall and Ellis (1946). Titrations were made with N/80 or N/100 thiosulfate using a burette graduated to 1/20 milliter in order to increase the accuracy of the readings.

Carbon dioxide and alkalinity were determined by the procedures recommended in standard method for the analysis of water and sewage (American Public Health Association 1936).

The pH for brook trout and brown trout was determined colorimetrically on a Hellige comparator, while for the other species it was determined electrometrically with a Leeds and Northrop pH meter.

In all experiments the fish were unfed for a period of at least 48 hours previous to use, since it was observed that erratic and non-reproducible results were often obtained when they were fed at a shorter interval before use. In starting experiments involving a change of water source, a period of approximately a week was given to acclimatize the fish to the new water supply. A period of approximately 24 hours or more was given for acclimatization to ascending experimental temperatures before beginning the experiments. With the wild rainbow trout, taken from a stream at winter temperatures, a period of 5 days was given for acclimatization to the initial temperature of 52° F. and change to the experimental water. It is realized that these initial periods may be short for full acclimatization to temperature. However, the temperatures involved do not approach closely the physiological limitations to temperature of the species concerned. Daily temperature fluctuations in a natural stream will often exceed those involved in the stepwise increase of temperature in these experiments. No indication of significant variation was noted between the initial and final studies at any temperature, even though the period for the completion of the experimental work at a single temperature sometimes exceeded a week.

Hatchery trout were fed on a liver diet for some time previous to experimental use. The bass after removal from their natural habitat were fed with natural foods (white worms, tubifex, and fry of other species of fish) before experimentation. No feeding took place during experimental runs.

The experimental water used for the brook trout studies was

Rochester, N. Y. tapwater having a pH of 7.2 to 7.3, carbon dioxide of 0.5 to 1.0 p.p.m., and a methyl orange alkalinity of 57 to 60 p.p.m. On the basis of three analyses provided by William A. Ryan, City Chemist for Rochester, the following fluctuation in composition is indicated. Except for pH, all figures are in parts per million.

Oxygen (dissolved) ...8.1-9.2	Sodium .....trace
Carbon dioxide (CO_2) .0-trace	Potassium .....trace
Alkalinity (as $CaCO_3$) ..52-61	Sulphate (as SO_4) ..18.6-22.9
pH 7.7-8.0	Chloride (as Cl) 3-4
Total solids.....96-110.8	Nitrate & nitrite (as N_2) 0.15-0.8
Calcium (as Ca) 21.3-23.0	Ammonia (as N_2) 0.0-0.1
Magnesium (as Mg) ..4.3-6.0	Silica (as SiO_2) 1.4-4.0
Iron (as Fe) 0.05-0.1	Manganese (as Mn) .....Nil
Iron and aluminum oxide 2.3-3.5	Calculated hardness.71.4-81.7

The specific conductance (in reciprocal ohms) was determined at the Rochester Pollution Laboratory to be 0.0001643 at 23° C. on May 14, 1953.

For the remainder of the studies, spring water from the Rome Fish Hatchery supply was used. The pH of this water ranged from 7.2 to 7.9, carbon dioxide from 1.6 to 4.4 p.p.m., and the methyl orange alkalinity approximated 100 p.p.m. during these experiments. A complete analysis of this water (as of November 27, 1949) follows:

Oxygen (dissolved) 8.9	Bicarbonate (as HCO_3) ..110
6-day B.O.D.....0.3	Sulfate (as SO_4) 16
Carbon dioxide (CO_2) ...2.0	Chloride (as Cl) .....Nil
Alkalinity (to M.O.) 95	Nitrate & nitrite (as N_2) .0.432
pH 7.5	Ammonia (as N_2) .....Nil
Total solids.....136	Total phosphorous (as P) 0.0025
Loss on ignition.....67	Silica (as SiO_2) 5.0
Calcium (as Ca) 34.5	Total manganese (as Mn) .Nil
Magnesium (as Mg) 5.6	Specific conductance (in reciprocal ohms)
Iron (as Fe) .....Nil	0.0000743 at 12½°C.
Aluminum (as Al) .....Nil	
Sodium (as Na) 2.1	
Potassium (as K) 0.47	

DISCUSSION

The results of the experiments carried on will be given separately for the four species of fish studied.

BROOK TROUT

Fry (1951) has reported that lethal oxygen levels for brook trout have been fully investigated by Graham, though, because the fish were acclimatized to oxygen concentrations near saturation values, the results are somewhat higher than they would be if the fish had been acclimatized to low oxygen, as demonstrated at a single temperature by Shepard. Fry presents data from both authors for a temperature of 49° F. and extrapolates Shepard's data to indicate an ultimate minimum tolerance of 0.9 p.p.m. oxygen at this temperature.

Gutsell (1929) reported a slow acclimatization of brook trout at 60° F. to a level of oxygen from 1.2 to 1.0 p.p.m.

Jahoda (1947) reported a slow acclimatization of brook trout in pools in a dried up stream to as low as 1.1 p.p.m. of oxygen at a temperature of 52° F.

During 1944, studies were made on oxygen concentrations lethal to brook trout using a total of 65 yearling fish from the Bath Fish Hatchery. The mean turnover time was 1 hour and 45 minutes. The data are summarized in Table 1.

TABLE 1. SUMMARY OF DATA ON LETHAL OXYGEN CONCENTRATIONS (IN PARTS PER MILLION) FOR BROOK TROUT FROM THE BATH FISH HATCHERY

Number of fish	Temperature in degrees F.	Oxygen concentrations found lethal				Standard deviation	Standard error
		Maximum	Minimum	Median	Mean		
18	55 ±1	2.00	1.15	1.58	1.59	±0.209	±0.049
19	60 ±1	2.35	1.35	1.85	1.84	±0.286	±0.066
14	66 ±1	3.20	1.60	2.23	2.21	±0.425	±0.114
14	70 ±1	3.40	1.70	2.60	2.54	±0.386	±0.103

The curve for the mean oxygen concentrations found lethal (Figure 1) was constructed at four temperatures from 55° to 70° F.

The equation for this curve may be represented by:

$$\text{Log. } Y = 0.0135X - 0.54326$$

The curve, extended to a temperature of 49° F. falls almost exactly midway of Graham's data for this temperature as given by Fry (1951) and Shepard's data as extrapolated by Fry in the same paper. If the variation between the most and least resistant fish remains at about the same spread as at 55° F. the upper and lower tolerance limits

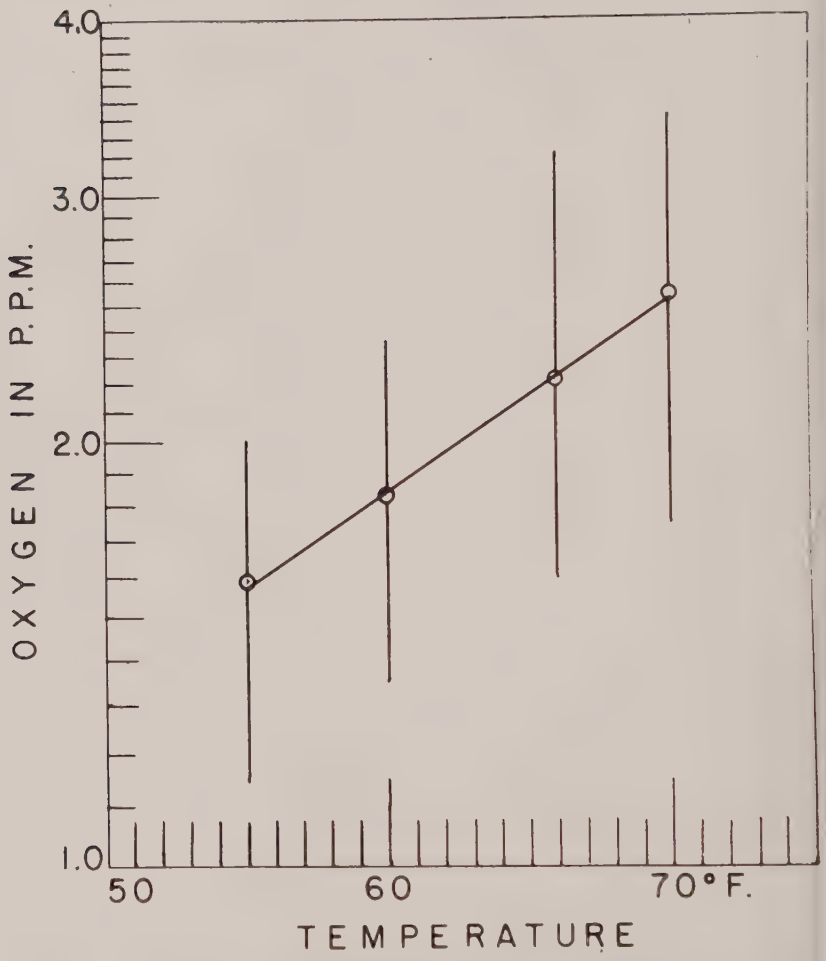

Figure 1. Mean lethal oxygen levels for brook trout from the Bath Fish Hatchery; range of individual data shown by vertical lines.

stated to have been established by Graham and Shepard would be approached. Neither paper is available here for direct comparison and, as one point is inadequate for comparative analysis, the apparent relationship may be entirely accidental.

Brown Trout

Gardner and Leetham (1914) determined the asphyxial point for brown trout at a number of temperatures. Their results indicate an increased oxygen requirement with increased temperature, though

their data do not fall in a straight line on semi-logarithmic paper after transforming to parts per million. Their data, in the range of the temperatures appearing on Figure 2, are presented upon the same graph as are the data from this Department's laboratories. It should be noted that the general slope of the line is somewhat similar though all points do not fall in proximity to a straight line.

Determination of mean lethal oxygen concentrations for brown trout was conducted in the Rome Laboratory in 1950, using four temperatures from 49° to 69° F. Sixty-five yearling fish from the

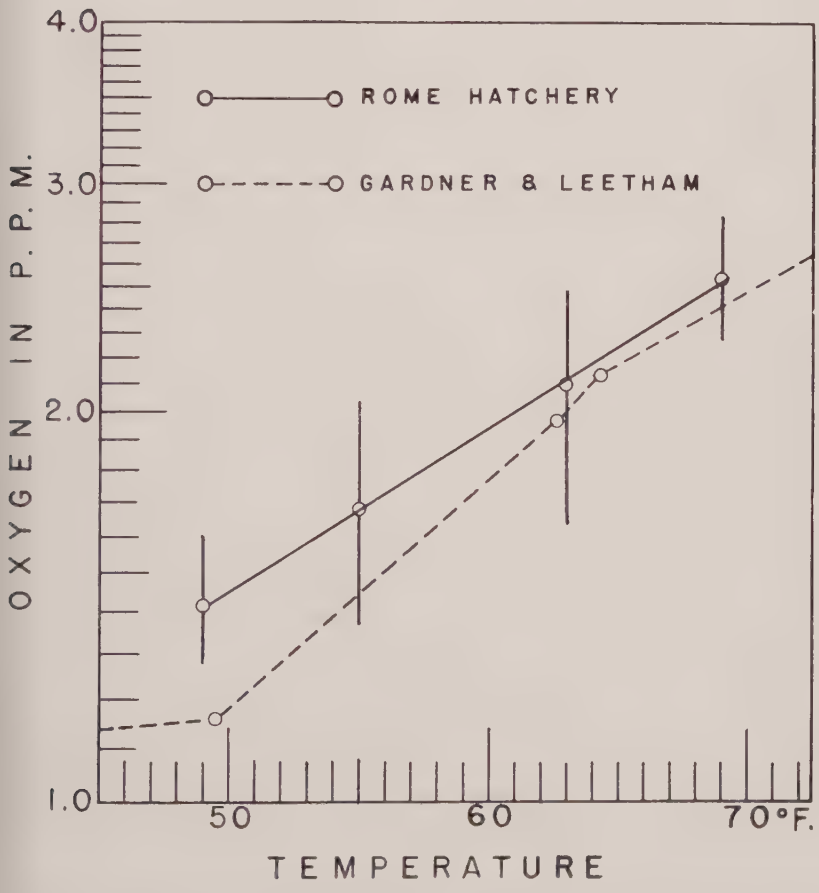

Figure 2. Mean lethal oxygen levels for brown trout from the Rome Fish Hatchery and part of Gardner and Leetham's data (1914); range of individual data shown by vertical lines.

Rome Hatchery stock were used in the individual experiments. The mean turnover time was approximately 2 hours and 33 minutes, varying from approximately 3 hours and 15 minutes at 49° and 55° F. to 1 hour and 40 minutes at 69° F.

Table 2. Summary of Data on Lethal Oxygen Concentrations (in parts per million) for Brown Trout from the Rome Fish Hatchery

Number of fish	Temperature in degrees F.	Oxygen concentrations found lethal				Standard deviation	Standard error
		Maximum	Minimum	Median	Mean		
8	49	1.60	1.28	1.45	1.42	±0.104	±0.037
18	55	2.03	1.37	1.69	1.68	±0.191	±0.045
18	63	2.48	1.64	2.11	2.10	±0.212	±0.050
16	69	2.82	2.27	2.51	2.53	±0.179	±0.045

Data are summarized in Table 2 and the graph of the curve appears in Figure 2.

The equation for this curve may be represented by:

$$\text{Log. } Y = 0.01248X - 0.46056$$

Rainbow Trout

Townsend and Earnest (1940) present a table including the work of Townsend, Eriksen and Earnest on this species which gives the minimum oxygen tolerance at 52° to 55° F. as from 1.50 to 1.54 p.p.m. These levels are appreciably higher than the results obtained here for either hatchery stock or wild-reared fish from an unpolluted stream.

In 1953, two sets of data were obtained at the Rome Laboratory on lethal oxygen concentrations for rainbow trout. The first was from 154 fish with a mean total length of 109.8 millimeters (4.32 inches) and a mean weight of 12.3 grams. These fish were from eggs collected from breeders at the Caledonia Hatchery and hatched and reared at the Rome Hatchery. The parent stock had been subject to low summer oxygen concentrations with a high level of fluctuation. The mean turnover time was 3 hours and 28 minutes, varying at the four experimental temperatures from 2 hours and 43 minutes to 4 hours and 16 minutes.

The other data are based on 130 fish from natural reproduction and growth in Grout Brook, the inlet of Skaneateles Lake. Fish collected fell in the 1- and 2-year age groups and ranged in size from 59 to

144 millimeters in total length (2.54 to 5.67 inches), with a mean length of 97.5 millimeters (3.80 inches) and a mean weight 8.5 grams. No significant difference in sensitivity to low oxygen was found between the 1- and 2-year fish, so the data are not separated. The mean turnover time was 4 hours and 37 minutes, ranging from 3 hours and 6 minutes at a temperature of 68° F. to 5 hours and 43 minutes at 52° F.

Table 3 summarizes the data for both hatchery and naturally spawned fish and the curves for mean lethal oxygen concentrations are plotted in Figure 3.

TABLE 3. SUMMARY OF DATA ON LETHAL OXYGEN CONCENTRATIONS (IN PARTS PER MILLION) FOR RAINBOW TROUT

Number of fish	Temperature in degrees F.	Oxygen concentrations found lethal				Standard deviation	Standard error
		Maximum	Minimum	Median	Mean		
		Rome Hatchery					
40	52.0	1.42	0.83	1.09	1.10	±0.141	±0.022
38	60.0	1.71	0.93	1.34	1.33	±0.192	±0.031
39	65.3	2.06	1.05	1.52	1.54	±0.218	±0.035
37	71.1	2.47	1.37	1.83	1.82	±0.291	±0.048
		Grout Brook					
30	52.0	1.27	0.81	1.06	1.05	±0.116	±0.021
32	60.6	1.51	1.05	1.26	1.27	±0.112	±0.020
29	65.0	1.91	1.14	1.38	1.40	±0.185	±0.034
39	68.0	1.92	1.08	1.49	1.51	±0.230	±0.037

The equation for the rainbow trout from the hatchery stock may be represented by:

$$\text{Log. } Y = 0.01145X - 0.55783,$$

The equation for the wild raised fish is:

$$\text{Log. } Y = 0.00979X - 0.48858$$

SMALLMOUTH BASS

Weibe, McGavock, Fuller and Markus (1934) present evidence indicating that, at a pH range within the limits found during these experiments, the lethal oxygen concentration at 25° C. (77° F.) lies

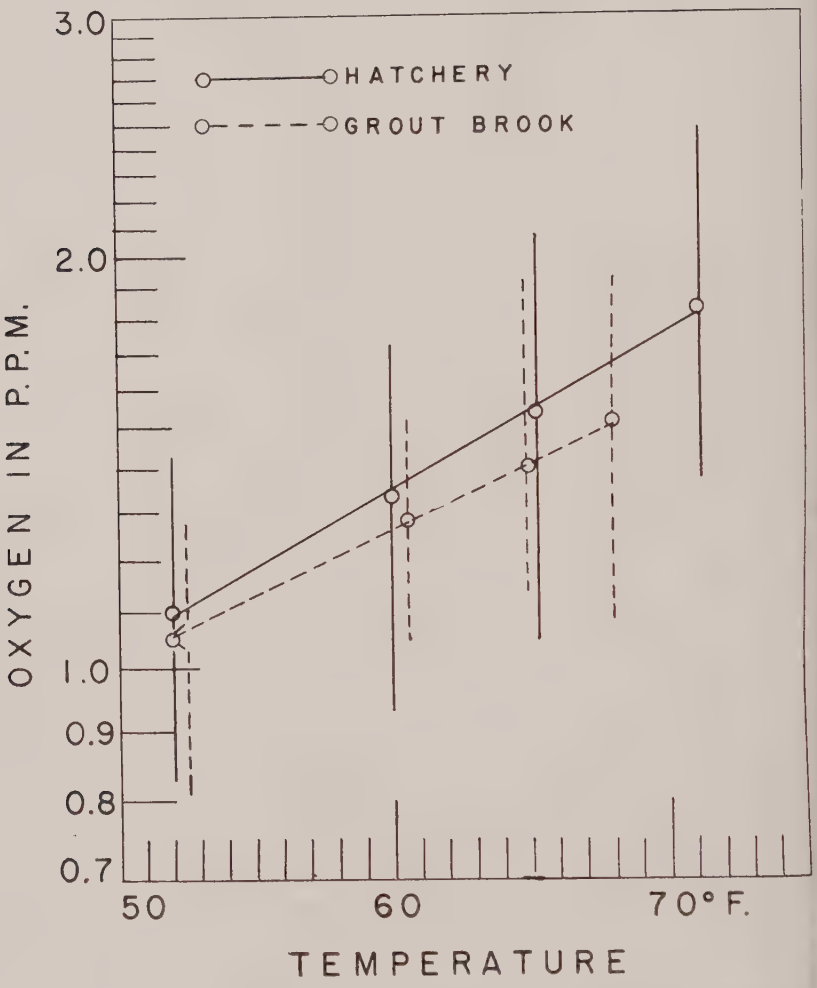

Figure 3. Mean lethal oxygen levels for hatchery and wild rainbow trout; range of individual data shown by vertical lines.

at about 0.4 to 0.5 p.p.m. Since this is reported in such a way as to indicate that this is the lowest concentration at which the species is able to extract oxygen from the water, it is assumed that this represents results from the fish least sensitive to reduced oxygen concentration and cannot be compared to a figure for mean lethal oxygen concentration.

Studies on the resistance of smallmouth bass to lowered oxygen were undertaken at Rome in 1952-53. No hatchery fish were available

for use in the determination of lethal oxygen concentrations for smallmouth bass. Seventy-two fish obtained from the Deer River were acclimatized to the experimental water at the initial temperature to be used and the study started. Later, an additional 75 fish were obtained from Beebe Lake and the experimentation continued. Plotting of the means of the combined data from the two sources failed to produce a satisfactory curve since the number of fish from each source at each temperature was not the same. The data were then treated as two separate populations and two curves were constructed. The lower sensitivity of the Beebe Lake fish to low oxygen concentration may be theoretically explained on the basis that oxygen acclimatization in a lake might be at a somewhat lower level than would be the case in a rapidly flowing, relatively unpolluted stream, or it might represent a population difference.

The mean total length of the Deer River fish was 70 millimeters (2.76 inches) and the mean weight was 4.04 grams. The mean turnover time was 8 hours and 24 minutes, that for the individual temperatures ranging from 5 hours and 19 minutes to 9 hours and 12 minutes.

TABLE 4. SUMMARY OF DATA ON LETHAL OXYGEN CONCENTRATIONS (IN PARTS PER MILLION) FOR SMALLMOUTH BASS

Number of fish	Temperature in degrees F.	Oxygen concentrations found lethal				Standard deviation	Standard error
		Maximum	Minimum	Median	Mean		
			Deer River				
29	54.0	0.95	0.58	0.72	0.74	±0.083	±0.015
20	60.0	0.98	0.63	0.87	0.83	±0.121	±0.028
14	70.0	1.23	0.77	0.91	0.96	±0.138	±0.037
9	80.0	1.32	0.99	1.17	1.15	±0.132	±0.044
			Beebe Lake				
20	52.5	0.85	0.48	0.63	0.63	±0.142	±0.032
15	60.0	1.10	0.48	0.73	0.73	±0.145	±0.037
20	70.0	1.19	0.61	0.86	0.87	±0.133	±0.030
20	80.0	1.56	0.72	1.03	1.08	±0.221	±0.050

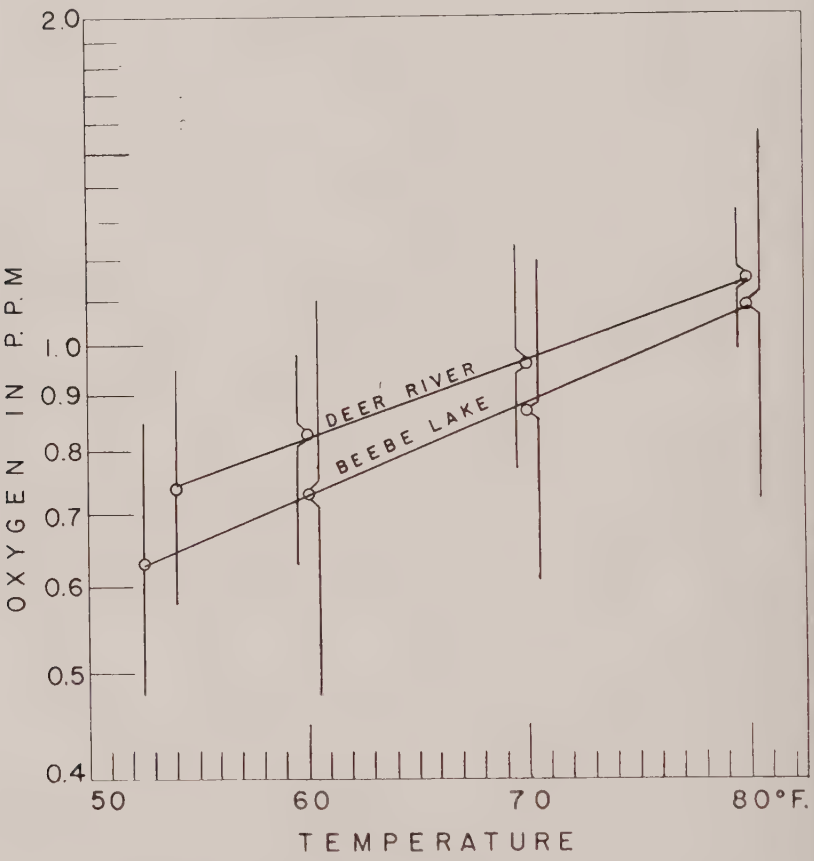

Figure 4. Comparison of mean lethal oxygen levels for stream and lake populations of smallmouth bass; range of individual data shown by vertical lines.

The mean total length of the Beebe Lake fish was 69 millimeters (2.72 inches) and the mean weight was 3.98 grams. Mean turnover time was 7 hours and 49 minutes, that for the different temperatures varying from 6 hours and 19 minutes to 9 hours and 50 minutes.

Table 4 summarizes the data on the fish from the two sources. The curves of the mean lethal oxygen concentrations appear in Figure 4.

For the Deer River fish the equation is:

$$\text{Log. } Y = 0.00723X - 0.51936$$

and for the Beebe Lake fish:

$$\text{Log. } Y = 0.00842X - 0.64366$$

LITERATURE CITED

American Public Health Association. 1936. Standard methods for the examination of water and sewage. 8th Ed. Am. Pub. Health Assn., New York.

Ellis, M. M., B. A. Westfall, and Marion D. Ellis. 1946. Determinations of water quality. U. S. Dept. Int., F. & W. Serv. Res. Rep. 9.

Fry, F. E. J. 1951. Some environmental relations of the speckled trout *(Salvelinus fontinalis)*. Reprinted from Proc. of N. E. Atlantic Fish Conf. (mimeo.)

Fry, F. E. J., V. S. Black, and Edgar C. Black. 1947. Influence of temperature on the asphyxiation of young goldfish *(Carassius auratus* L.) under various tensions of oxygen and carbon dioxide. Biol. Bull. 92(3):217-224.

Fry, F. E. J. and J. S. Hart. 1948. The relation of temperature to oxygen consumption in the goldfish. Biol. Bull. 94(1):66-77.

Gardner John Addyman and Constance Leetham. 1914. On the respiratory exchange in fresh-water fish. Pt. 2. On brown trout. Biochem. Jour. 8:591-597.

Gutsell, James S. 1929. Influence of certain water conditions, especially dissolved gasses, on trout. Ecol. 10(1):77-96.

Hart, J. S. 1945. The circulation and respiratory tolerance of some Florida fresh-water fishes. Proc. Fla. Acad. Sci. 7(4):221-246.

Jahoda, W. J. 1947. Survival of brook trout in water of low oxygen content. Jour. Wildlife Mgt. 11(1):96-97.

Townsend, Lawrence D. and Don Earnest. 1940. The effects of low oxygen and other extreme conditions on salmonoid fish. Proc. 6th Pac. Sci. Cong. Vol. 3:345-351.

Wiebe, A. H., A. M. McGavock, A. C. Fuller, and Henry C. Marcus. 1934. The ability of fresh-water fish to extract oxygen at different hydrogen-ion concentrations. Phys. Zool. 7(4):435-448.

WARINESS AS AN INFLUENCE ON AGE COMPOSITION OF WHITE-TAILED DEER KILLED BY HUNTERS[1]

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ABSTRACT

Appraisals of the age composition of a wild deer population based on the legal deer kill during the open season would be of little value in research or management if the kill were not representative of the wild population. Differential wariness between age classes is a possible factor that might affect the representativeness of the kill. Data that could be used to evaluate this possibility were available in the checking station records of deer killed by hunters during the period from 1943 to 1952. Tests to find the magnitude of biases indicated that the checking station samples were representative of the age composition of the kill. Influences other than wariness, that might bias the composition of the kill in relation to that of the wild population, were judged not to affect unduly the randomness of the kill except with respect to fawns. Analysis of the data indicated that, considering the open season as a whole, wariness does not significantly distort the age composition of the legal kill of adult deer in relation to that of the corresponding wild population.

There are many stories to the effect that older deer are more wary than younger ones and, as a consequence, more difficult to bag. If this should be a valid generalization, then the number of wary old deer in the hunter kill would be disproportionately low in comparison with that in the wild population, thus impairing the usefulness of age composition estimates derived from kill records.

For a number of years game technicians in New York have been measuring and estimating the age of deer killed by hunters in an effort to determine regional differences in size, antler dimensions, productivity, and trends in population composition and abundance. A major problem associated with this work is the question of whether the age composition of such a sample can be assumed to be representative of the entire population in the area from which it was derived.

This problem is a complex one due to the number of factors that must be considered. Some, such as wariness, hunter selectivity, and the effect of distance from roads in remote areas such as occur in the central Adirondacks, might directly affect the deer killed by hunters so that they would not be representative of the wild population. Others, such as the possibility that hunters are more likely to stop at a checking station with a large deer than with a small one, might

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-28-R.

affect the checking station sample as representative of the deer killed by hunters.

The main purpose here will be to evaluate the degree to which wariness affects the age composition of the deer killed by hunters in relation to that of the wild population.

PROCEDURE

The use of age data for a wariness study had not been envisaged at the time the roadside check system was organized. The possibility that a test of wariness could be made emerged when sufficient data were on hand to warrant an analysis of differences in age composition as the hunting season progressed. Fortunately, the methods used in collecting data for the major problems supplied information for such an analysis.

Large samples of the deer killed by hunting during the open season were secured from the major regions of New York State (Western, Catskill, and Adirondack) at checking stations established along roads which carried a heavy traffic of successful deer hunters. For the Western region, this was accomplished by manning six or eight stations for the entire 6-day hunting season. For the Catskills, three or four stations were manned on the first 2 days, each weekend, and the last day of the 16-day open season. For the Adirondacks, three or four stations were manned on the first four or five weekends of the 30- to 37-day open season. These time patterns were based on the hunting habits of the majority of hunters in each region and made possible a good sample of the deer killed throughout the season without an undue expenditure of time by station operators. The data collected from 1946 through 1952 provided a sample large enough for statistical analysis.

The checking station data were assembled and tabulated by year, region, sex, age, and date of kill. Statistics derived from these data were used for tests of significance. To determine whether apparent differences were significant, the "standard error of the difference between two means" was calculated and the values obtained were compared with Fisher's "Table of x" (Paterson, 1939, p. 247). A significant difference was one in which the probability was greater than 19 to 1 against its being due to chance.

Because of the possibilities of bias, no completely objective conclusions can be drawn from the data on which this study is based. This need not, however, prevent using the available data in attempting to ascertain whether the influence of wariness is a significant factor

affecting the vulnerability of deer to hunting. Following is a brief discussion of the major potential biases recognized.

Hunter selectivity of large deer is a very difficult factor to evaluate objectively. Trophy head hunting is a possibility. However, the hunting pressure in the Catskill and Western regions is so heavy, and the desire to get a deer is so great among Adirondack deer hunters, that the great majority shoot at any legal deer. Because of these conditions, the effect of selectivity by a small percentage of the hunters is negated by the larger percentage of those who "just want a deer to take home". A point of selectivity regarding fawns will be discussed later.

Another factor that might affect the composition of the deer kill in comparison with that of the wild population is the relative accessibility (i. e., distance from roads and the presence of large areas closed to public hunting) of various parts of the range. In other words, may some sections have been hunted so lightly that the deer taken did not constitute a representative cross-section of the population existing there? Conditions in the several regions of the State differ widely in this respect. Within the territory open to deer hunting in the Western region, the peripheral Catskills, and the peripheral Adirondacks there are virtually no tracts that are not heavily hunted or that might be considered refuges for large numbers of deer except for a few private estates and State parks. Here, the influence of accessibility may be considered unimportant. On the other hand, in the central Catskills and, to a much greater degree, in the central Adirondacks, this factor may often be of appreciable significance. The possibility of its affecting the composition of the deer kill in the latter section will be discussed further in connection with the analyses of the data obtained.

Turning to factors that might affect checking station samples as representative of the composition of the actual deer kill, a major question is: Do hunters with small deer tend to avoid a checking station or conceal their deer while hunters with large deer do not? To answer this several tests were made.

In the Western region there has been a heavy traffic of deer (500 to 700 deer checked in one day) at the South Wales station on opening days and Saturdays. Because of this, game protectors and State police have handled the traffic problem on such occasions. To do this, these officers stopped all cars to determine whether they carried deer. Those with deer were directed into a line going to the checking station while those without deer were not detained. Samples secured on days with a compulsory check and those obtained on days with a voluntary check had virtually the same age composition.

The South Wales station was operated annually from 1946 to 1952. Other stations in the same region (at Painted Post, the Arnot Forest, Binghamton, Geneseo, Horseheads, and Owego) were not operated each year, but deer coming to all of them were from areas where deer hunting pressure and reproductive rates were almost the same. Hunters became accustomed to the South Wales station and could have avoided it if they had small deer that they did not wish to exhibit or they could have brought large ones to the station. When the other stations were operated their existence was given little advance publicity and this was believed to have been largely ineffective. Therefore, on the first day or two of operation, they were new and hunters with small deer who wished to avoid being checked would have had no reason to change their route of travel on that account. The samples from all stations, when arranged according to the county from which the deer came, had virtually identical age compositions.

In the Catskills, one station was operated each year from 1946 through 1952 while others were established in 1950 (two) and 1952 (one). The samples from similar counties of origin collected at all four stations, and from a new station in comparison with an old one, had similar age compositions.

In the Adirondacks, the test was slightly different. Here, spike-horned deer are common and many have antlers that are just legal (3 inches long). Thus, in addition to age records, data were obtained on whether hunters with spike-horned deer tend to avoid stopping at checking stations more than those with better trophies. Comparisons were made on one weekend in each of four years and on three weekends in a fifth. On these occasions voluntary checks were run all day Saturday and on Sunday until about 3:00 or 4:00 p.m., while from then until near midnight a compulsory check of all cars (with or without hunters) was made. This compulsory check was for law enforcement—either game law, immigration law or traffic law -and the two activities were combined at the same station. It was found that the age composition and frequency of spike-horned bucks in the compulsory and voluntary samples were virtually the same.

In the Catskill and Adirondack regions during certain years when antlered deer only were legal as much as 20 to 25 per cent of the samples was secured by direct visits to hunting camps. When information was secured in this manner it was compared to that secured at checking stations. The two sets of data, although differing in size, showed virtually identical age compositions.

These tests indicated that New York hunters neither concealed

enough small deer and bucks with poor heads nor brought enough large deer and bucks with large heads to the checking stations to bias the samples. Over the period of years checking stations have been operated (1943 to 1952) there have been instances in which hunters have driven as much as 50 miles out of their way to bring deer to a station. However, in discussing these occasions with station operators after the season each year, there has been no indication that any particular group of deer (small, medium, or large; small racks or large racks) was brought to stations with exceptional frequency.

Another potential bias in the data concerns age determination by technicians at checking stations. Inaccuracies are always a possibility and several steps have been taken to minimize them. To begin with all non-project personnel responsible for determining age have had a period of instruction prior to a field assignment as well as a refresher course each subsequent year. This training involved a full day of intensive review of about 500 deer jaws at the laboratory and a test on about 50 jaws which each trainee had to pass. This was followed by at least one and generally two days with the project leader or assistant leader at a station in the Adirondacks (where the season opened first) during which differences were ironed out under field conditions.

To test the accuracy of the age records obtained, the data from each station were tabulated separately and compared with data from other stations for deer that came from the same section of the State. In addition the age records for yearlings were divided into the 1 year and 5 month, the 1 year and 6 month, and the 1 year and 7 month classes. This grouping would usually reveal whether a technician was able to differentiate correctly between deer 1 year and 7 months old and those 2½ years old. Three sets of records were found to be of doubtful value and were discarded. In addition to these comparisons, the location of checking stations has made it possible for an occasional hunter to pass through as many as three such points with the same deer. There also have been several skeptical hunters who have deliberately taken their deer to two or three stations. In these accidental and deliberate tests by hunters, training has paid off. In some 20 known instances determined ages by different technicians for an individual deer have all been identical. It, therefore, seems that no significant inaccuracies exist in the age data recorded.

Having established the fact that the checking station records may be considered representative of the composition of the actual deer kill, the mode of reasoning with respect to the significance of wariness involves an appraisal of the similarity or dissimilarity of the composi-

tion of the deer kill and that of the wild population from which it was derived. To determine this, the mean ages (or the age distributions) for successive days or periods of the open season were compared in terms of the available knowledge of the wild population and its behavior in relation to hunting. If, at the beginning of the season, a disproportionately large number of young deer were taken, it would follow that they were less wary. If this disparity later diminished significantly, then one would conclude that these deer became more wary as the season progressed. If no disparity were found, wariness would not be considered an important influence on the composition of the kill.

FINDINGS

The information secured will be presented separately for adult males, adult females, and fawns.

Adult Males

For adult males sufficient data were available for each of the three regions to warrant separate analysis.

Western Region The figures for the Western region are given in Table 1 and reveal that the mean age (1.87) for bucks killed on the first day of the 6-day hunting season was significantly lower than that (1.93) for those killed during the following 5 days of the season. Because the mean ages for the second through the sixth days were not significantly different the data for this period were combined. A test of significance for bucks 2½ years of age and older does not show a significant difference between the means for the first day as compared with those for the last 5 days. It is evident, therefore, that the kill of yearlings during at least one of the two periods was disproportionate to the relative frequency of this age class in the wild population and that the percentage of yearlings in the kill declined from the first

Table 1. Comparative Age Distribution of Adult Male Deer Taken During Different Periods of the Open Season in the Western Region (1946-52)

Period of season	Age in years									Total	Mean age
	1½	2½	3½	4½	5½	6½	7½	8½–9½	10½+		
First day	1679	360	137	32	9	9	2	1	..	2229	1.87
2nd to 6th	1311	304	151	34	9	5	1	2	..	1817	1.93
Total	2990	664	288	66	18	14	3	3	..	4046	1.90

period to the second. In view of this, it seems most likely that the kill of yearlings the first day was disproportionately high and that the subsequent decline resulted from a change in behavior of the yearling deer, namely, an increase in wariness. On the last 5 days the mean ages did not show progressive increases, being 1.94, 2.01, 1.91, 1.89, and 1.90 for the second through the sixth days, respectively. It seems logical to conclude that wariness, though a characteristic of older deer, is rapidly acquired by yearlings and is not a factor tending to make these deer more vulnerable after the first day of hunting in this region. It is also concluded that, for the season as a whole, the composition of the kill is reasonably representative of that of the wild population.

Catskill Region In the Catskills, the mean age for bucks killed on the first day (1.98) was significantly lower than that (2.12) for bucks killed on the following 15 days (Table 2) while there was

Table 2. Comparative Age Distribution of Adult Male Deer Taken During Different Periods of the Open Season in the Catskill Region (1946-52)

Period of season	Age in years									Total	Mean age
	1½	2½	3½	4½	5½	6½	7½	8½–9½	10½+		
First day	479	162	62	15	2	1	..	..	..	721	1.98
2nd to 16th	958	440	169	47	10	5	3	1	..	1633	2.12
Total	1437	602	231	62	12	6	3	1	..	2354	2.08

no significant difference between the two periods for those 2½ years of age and older. Also, the percentage of yearlings in the kill declined from the first period to the second. Thus it seems probable that the influence of wariness in this region, as in the Western region, was significant only on the first day of the season. It may be noted, too, that the mean age for the second to the eighth day was 2.10 as compared to 2.16 for the ninth to the sixteenth day. Here, again, it seems that the kill for the season as a whole is representative of the wild population.

Adirondack Region In the Adirondacks, also, the mean age for the bucks taken at the beginning of the open season was significantly lower than that for those taken later. Unlike the records for the other regions, however, a change of this kind occurred among the deer 2½ years of age and older. Furthermore it was progressive throughout the season. The figures are given in Table 3 in which they are grouped by 5-day periods in order to smooth out variations

TABLE 3. COMPARATIVE AGE DISTRIBUTION OF ADULT MALE DEER* TAKEN DURING DIFFERENT PERIODS OF THE OPEN SEASON IN THE ADIRONDACK REGION (1946-52)

Period of season	Age in years									Total	Mean age
	1½	2½	3½	4½	5½	6½	7½	8½–9½	10½+		
1st to 5th day..	412	369	149	42	24	14	10	7	..	1027	2.54
6th to 10th.....	250	244	111	39	20	14	7	6	3	694	2.72
11th to 15th....	183	227	133	44	18	12	13	7	..	637	2.89
16th to 20th....	325	435	250	70	42	33	28	18	7	1208	3.03
21st to 25th..	256	356	198	89	44	22	14	19	4	1002	3.06
26th to 30th....	102	116	74	34	22	15	5	9	2	379	3.20
31st to 37th....	9	16	11	7	1	5	2	..	..	51	3.46
Total.....	1537	1763	926	325	171	115	79	66	16	4998	2.89

* Applies only to legal bucks having antlers at least 3 inches long.

in the relatively small number of deer checked each day. The positive correlation between the mean age and the period of kill is consistent and significant. At the same time, the percentage of yearlings in the kill declined steadily as the season advanced.

Because the age composition of the samples for the various periods of the season were all different, no one of them can be considered representative of the wild population. The decline in the relative frequency of yearlings in the kill seems to indicate that this age class became more difficult to bag as the season progressed and, in view of the findings for the other two regions, that this resulted from the development of wariness in these animals.

On the other hand, the possible relationship of wariness to the increase in mean age of the older group is more difficult to assess. Several factors are involved which are not important in the Western and Catskill regions.

First, much of the range in the Adirondacks is relatively remote from roads or other means of easy access and the average number of hunters per square mile is low throughout the season. Over a period of years this has resulted in a higher mean age for the deer population than in the case of more heavily hunted territory. Moreover, experience has shown that these areas are hunted most intensively late in the season. Thus a random kill would have a higher mean age and would exert its greatest influence in the late season data. To some extent, then, this situation minimizes the degree to which wariness can be considered responsible for the increased mean age recorded.

Another factor peculiar to the Adirondack region is the fact

that substantial proportions of the adult bucks in the younger age classes lack legal antlers. This is mainly true of yearlings, especially during seasons following severe winters. Unfortunately, the percentages cannot be accurately estimated except during a deer-of-either-sex season. The only recent season of this kind in this region was in the fall of 1943 which followed a moderately severe winter. At that time 68 bucks in the yearling, 2½-year, and 3½-year age classes were checked. The frequency of those lacking legal antlers is given in Table 4.

Table 4. Comparative Frequency of Adult Male Deer Lacking 3-Inch Antlers Recorded for the Adirondack Region in 1943

Data recorded	Age in years		
	1½	2½	3½
Number checked	39	13	16
Number lacking legal antlers	21	2	1
Per cent of number checked	53 8	15 4	6 3

The existence of this condition makes it apparent that it would be well-nigh impossible for the legal kill for the years covered by Table 3 (or during any season in this region for antlered deer only) to have been representative of the wild population with respect to age composition. There is sound evidence that such a lack of legal antlers is present every year to some degree and is especially pronounced following severe winters. But there are no data from which its magnitude can be accurately estimated for any of the seven years under consideration. The fact that, as a result of this condition, a substantial portion of the bucks in the younger age classes in the actual population were immune to legal hunting, is a major reason for the average mean age of the bucks taken in this region being higher than that for the other regions. It does not bear on the progressive rise in the mean age of the 2½-year and older deer recorded.

Despite the existence of this source of error, a rough correction can be made through extrapolation. It is known that a relatively stable population, such as exists in the Adirondacks, can be described by a curve showing a smooth decrease from the youngest to the oldest age class. Thus, when the age composition derived from checking station data shows a distortion for certain of the younger age classes, an extrapolation of the curve for the other age classes will provide approximations of their actual values. It is felt that, by using a full season's data

in this way, a reasonably accurate appraisal of the age composition of the wild population can be obtained.

With respect to wariness, it is more difficult to draw conclusions for the Adirondack region than for other parts of the State. As has been pointed out, the number of variables in the data recorded, in the environment, and in the hunting conditions are greater there than elsewhere. In the main, the influence of these factors cannot be accurately assessed. For yearlings, the evidence indicates that they are less wary at the beginning of the open season than later. For older deer the picture is not clear. It may be that, in remote areas or in other localities when hunting pressure is light, some older animals may be less vulnerable because of superior wariness. On the other hand, the higher mean age of the overall kill of bucks in such areas can be attributed to an actually higher mean age of the wild population. Beyond this, present knowledge will permit only speculation.

Adult Females

For adult females sufficient data were available only for the Western region for 1948 and 1952. Although there was an open season for antlerless deer in 1950, such hunting was permitted on only 1 day and, hence, the data are not pertinent to the present topic. The records for the two applicable years are given in Table 5.

Table 5. Comparison of the Mean Ages of Adult Female Deer Taken on Each Day of the Open Season in the Western Region in 1948 and 1952

Day	1948		1952	
	Number checked	Mean age	Number checked	Mean age
1st	165	3.10	300	2.32
2nd	161	2.81	473	2.41
3rd	97	2.78		
4th	93	3.06		
5th	20	2.60		
6th	20	2.70		

These figures, those for 1948 in particular, reveal a trend in mean age that is contrary to what would be expected when wariness is a decisive factor. On this occasion, both antlerless and antlered deer could be hunted concurrently on all 6 days of the open season. The figures for the take of antlerless deer permitted concurrently on the last 2 days only of a 6-day buck season in 1952 are not significantly

different. Thus, no relationship between wariness and vulnerability to hunting is indicated by these data.

Fawns

Whether or not fawns exhibit wariness is difficult to determine. Some information is available for the Western and Catskill regions in 1948 and 1952 when fawns were taken in connection with the hunting of antlerless deer. The question was approached by comparing, for different periods of the open season, the ratio of female fawns to yearling does checked. The data are given in Table 6.

Table 6. Ratio of Female Fawns to Yearling Does Taken in the Western and Catskill Regions in 1948 and 1952

Year	Region	Period of season	Specimens recorded		Female fawns per 100 yearling does
			Fawns	Yearling does	
1948†	Western*	First day	184	156	118
		2nd to 6th	539	574	94
1952†	Western§	First day	156	205	76
		2nd day	318	279	114
	Catskill†	First day	87	98	90
		2nd day	134	114	117

* Concurrent open season of 6 days for both antlerless and antlered deer.
§ Concurrent open season of 2 days for both antlerless and antlered deer immediately following season of 4 days for antlered deer only.
† Concurrent open season of 2 days for both antlerless and antlered deer immediately following season of 14 days for antlered deer only.

For the Western region, in 1948 the kill of female fawns was considerably greater than that of yearling does on the first 2 days while both were about equal for the remainder of the 6-day season. In 1952, fewer fawns than yearling does were taken the first day but the reverse was true the second day. Part or all of this territory had had antlerless seasons in 1941, 1943, 1944, and 1946. Most of those hunting there had overcome any reluctance to kill does and many would take any deer that came along. In 1948, either the fawns were less wary the first day or the hunters made little effort to secure a larger deer—probably both factors were involved. The second year, however, it would seem that on the first day the hunters must have passed up many fawns with the hope of killing a larger deer.

For the Catskills, which in 1952 had its first antlerless season in recent years, the situation appears to have been similar to that in the Western region the same fall.

As in the case of adult females, no definite conclusions can be drawn from these data regarding wariness among fawns in relation to hunting. It seems likely that selectivity, or lack of it, by the hunter is a more decisive factor in determining the relative magnitude of the fawn kill.

CONCLUSIONS

For adult males, data from the Western and Catskill regions indicate that, at the beginning of the open season, yearlings are less wary than older bucks, but that the difference diminishes rapidly and is not significant after the first day of hunting. In the Adirondacks, the data are affected by variables not present elsewhere which make analysis more difficult. Nevertheless, the evidence indicates a similar basic relationship.

For adult females, there is no evidence that wariness affects their vulnerability to hunting.

For fawns, the attitude of the majority of the hunters afield as to whether or not they avoid shooting this age class is probably the dominating factor with respect to the proportion taken.

It may be concluded that, considering the open season as a whole, wariness does not significantly distort the age composition of the kill in relation to that of the corresponding wild population, except possibly for buck seasons of only 1 or 2 days duration.

A reliable appraisal of the age composition of the kill by hunting may be obtained through the operation of roadside checking stations. Analysis of the data available for this study indicates that hunters who have killed small deer do not conceal them from checking station operators or deliberately avoid checking stations in such large numbers as to bias age composition information. Neither do hunters with large deer go to these stations to an undue degree. It should be emphasized that, to be representative of the kill as a whole, sampling data must be taken continuously or periodically throughout the entire open season.

LITERATURE CITED

Paterson, D. D. 1939. Statistical technique in agricultural research. McGraw-Hill Book Co. New York.

THE EFFECTS OF DUCKS ON THE DEVELOPMENT OF FILAMENTOUS ALGAE IN FARM FISHPONDS

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ABSTRACT

To test the efficacy of ducks as controllers of filamentous green algae on farm fishponds, mallards were stocked on 21 farm ponds in south-central New York and on shallow ponds at the Cornell University Fish Hatchery at Ithaca. Observations were also made on three ponds bearing domestic mallard derivatives and muscovies. Field results indicated that the farm pond ducks had no appreciable effect on the algae. Observations at the hatchery suggested that, under conditions of concentration, ducks may destroy part of the algal mat by agitation or may retard development by increasing turbidity, but they are not capable of preventing undesirable amounts of algal growth.

The inclusion of farm fishponds in good land management programs has been favorably accepted by farmers, and many of these impoundments have been constructed in recent years. One of the most important values of farm ponds is their suitability for recreational use. Swimming, fishing, boating, skating, and improved hunting can be found here in addition to the great esthetic appeal. As is usually the case when man tries to bend nature to his own purposes, many management problems have arisen, and the development of large growths of filamentous green algae in many ponds has been highly detrimental to man's attempt to achieve some of the above-mentioned pleasures.

Algal and weed growths have created problems for as long as man has utilized water, so experiments with control measures are nothing new. Physical, chemical, and biological techniques have been tried, with the degree of success varying with the method, the specific weed, and the ultimate end desired. Probably the most common method is the removal of plants by cutters, dredges, and rakes of various design. This means of control is ordinarily a very temporary and unsatisfactory one, particularly when large amounts of algae or weeds are present.

Chemical controls have been highly popularized, but, as yet, no cure-all has been developed. A recently developed weed-killer (2, 4-D) was found to be lethal to *Vallisneria*, *Anacharis*, and *Myriophyllum* at a concentration of 100 p.p.m., but *Cladophora* remained unaffected (Gerking, 1948). Rotifers and pond snails were not killed by this concentration of 2, 4-D. An old stand-by, copper sulfate, has been frequently used with good results. It has even been successful in con-

trolling algae in cement ponds when added to navy paint (Herman and Anderson, 1947). Trout were not harmed under these circumstances, but copper sulfate and other chemicals can be very toxic to fish and other pond organisms if the concentration and method of application are not carefully controlled. This danger makes chemical control of algae somewhat undesirable for use by pond owners.

Reductions of algal growths have been achieved by two workers with the use of crayfish (Tiffany, 1938). Their effects were due to the increased turbidity of water resulting from bottom activity. Black (1946) suggested the use of the German carp in fish culture ponds to keep down the growth of water weeds. This vegetarian, however, would not be held in much esteem by the pond owners of the Northeast.

A recent letter to the Editor of the New York State Conservationist (Smith, 1952) indicated that mute swans kept on a 6-acre pond completely controlled all forms of waterweeds. Prior to the stocking, weed growths had been heavy enough to prevent rowing in the pond.

During the summer of 1950, a pond at Danby, New York, supported a dense growth of filamentous algae. After several domestic ducks were placed on the pond, the mat disappeared, and, since the ducks had been observed feeding in the mat, it was assumed that they might have caused its destruction. When a large number of wing-clipped mallards was made available to the Department of Conservation at Cornell University by the Bureau of Game Farms of the New York State Conservation Department, it was decided to test further the ability of ducks to control filamentous algae by stocking the mallards on farm ponds. The possibility of using ducks to control undesirable amounts of filamentous green algae is an attractive one, for the simplicity of the control measure would add incentive to the natural desires of many pond owners for ducks.

PROCEDURE

Of the mallards received, 26 pairs were stocked on 21 ponds in the counties of Chemung, Schuyler, Tioga, and Tompkins, as indicated in Table 1. Three other farm ponds bearing domestic ducks (Banfield, E. Miller, and Reisch) were kept under observation, and several mallards were held on a series of four small shallow ponds (about 10 inches deep) at the Cornell University Fish Hatchery at Ithaca, N. Y.

The latter four ponds were fenced to control the activities of

the ducks. Three of them were divided in two parts, while the entire fourth pond was left open to the adjacent one of the first three. Varying numbers of ducks were kept on these pond sections for different periods of time.

It was expected that the ducks concentrated on the shallow ponds at the hatchery would affect the algae: (1) by eating it; (2) by disturbing the "seed bed" on the bottom; (3) by increasing the turbidity of the water; or (4) by agitating the mat in normal feeding activities. Data on these factors were obtained by the following methods: (1) by direct observation; (2) by feeding the ducks corn placed on definite areas of the pond bottoms; (3) by analyzing water samples collected at different times with a Hellige turbidimeter; and (4) by observing the ducks and by stirring-up the algal mat in a corner of a pond section not occupied by ducks in simulation of duck activity.

Observations were begun in April and ended in October of 1951. During this period, the farm ponds were visited about five times each, and the hatchery ponds were visited almost daily. Notes were kept on the general appearance of the algae and on the relative extent to which they covered the pond, surface and bottom. A relative number was assigned to each pond to indicate the extent and duration of the blanket formed as follows: (1) traces or the absence of algae; (2) small amounts of algae; (3) large amounts of algae for part of the season; and (4) large amounts for the entire season. The order in which the ponds are listed in Table 1 is based on the relative severity of the algal nuisance.

FINDINGS

The development and changes of algae throughout the season on the farm fishponds are indicated in Table 1. The various concentrations of ducks are also shown. The effectiveness of the control obtained in the "field test" is quite apparent. The pond on which ducks "controlled" algae in 1950 (E. Miller) developed one of the most dense mats of all the ponds studied. The other two ponds (Banfield and Reisch) with part-time occupancy by domestic ducks (muscovies and unidentified mallard derivatives, respectively) also supported very dense growths of filamentous green algae. The Culver pond, though it eventually held 11 fully grown mallards, produced a mass of algae in excess of what it had the previous year. No wonder that the ponds with only one or two ducks failed to respond favorably to the treatment! The fact that some ponds bearing ducks had no dense algal growths can be attributed to the apparent vagaries of algal

Table 1. Relationships Between Algal Abundance, Presence of Ducks, and Size of Farm Fishponds.

Number and name of pond	Location	Abundance of dominant filamentous algae*			Degree of algal nuisance	Mallards stocked	Ducks present in September	Perimeter in feet
		May	July	Sept.				
1 Banfield	Horseheads	4r	4r,1c	4r	4	0	7	410
2 Saari	Mecklenburg	4r,1s,1c	3s,1r	4r	4	2	1	690
3 Culver	Mecklenburg	4r,3e,1s	3s,2r	4r	4	2	11	810
4 E. Miller	Danby	4r	4r,3m	4r	4	0	5	520
5 Lipka	Candor	4r,1s	3s,2r,2z	4r,1s	4	2	1	810
6 Old Fisher	So. Lansing	4r	3r,2s	4r,1s	4	2	0	710
7 Reisch	Candor	3e	4e,2s	4e,2s	3	0	7	430
8 Old Ettenburger	Elmira	3e	4s,3r	4r,3s	3	2	1	410
9 Burdick	Hector	3r	3s	3r	3	4	0	1450
10 Swanson	Ithaca	2e	3e	2e,1s	3	2	3	700
11 Old Ballard	Hector	1s,1m	3r,2s	3r	3	4	2	850
12 J. Miller	So. Lansing		1r	4r	3	2	1	840
13 Babcock	Ithaca	4r,2s	1r,1s	2r	2	2	9	700
14 Hadlock	Newfield	2r,2s	3r,2s	2r,2s	2	6	1	1240
15 Morris	Mecklenburg	2e,1s	2e,2s	1e	2	2	11	1080
16 Johnson	Newark Valley	3e	2e	2r	2	2	1	390
17 Beach	Apalachin	2s	2s	1r	2	2	2	950
18 Ketchum	Newark Valley	2r	2s		2	2	5	1200
19 Bierschank	Tioga Center	1e	2e,1s	2r	2	2	1	620
20 New Fisher	So. Lansing	1e	1e	1r	1	2	4	1140
21 New Ballard	Hector	1m		1e	1	2	1	900
22 Olin	Breesport	1c,1s			1	2	2	420
23 Murphy	So. Apalachin	1e			1	4	1	1140
24 New Ettenburger	Elmira				1	0	0	290
25 Teeter	Hector				1	2	0	540

* Numerals represent abundance as follows: 1 traces or few; 2—common; 3—abundant; 4—very abundant.
Letters represent genera as follows: c – *Cladophora*; e—*Oedogonium*; m – *Microspora*; r—*Rhizoclonium*; s—*Spirogyra*; z—*Zygnema*.

responses to a multitude of chemical, physical, and biological interactions in different ponds and not to the presence of the ducks.

More intensive study at the hatchery gave a definite answer to the question of the potentialities of mallards as controllers of algae. Although the birds frequently dabbled about the algal masses, they were never seen feeding directly on either *Spirogyra* or *Oedogonium*. On the other hand, a flock of young pintails, held temporarily in an inclosure containing several cement tanks bearing mats of *Oedogonium*, *Hydrodyction*, and *Lemna*, completely consumed the algae and the duckweed in several of the tanks.

The spotting of patches of corn on the pond bottoms yielded little information. The alga was inclined to develop unequally, and there was no sharp difference in its development between the spots where the ducks would supposedly concentrate their feeding and those areas where no corn was spread.

The degree of turbidity in the shallow ponds varied greatly. During periods when the ducks were active, the water became so turbid that the bottoms of the ponds could not be seen for several days. The turbidity at such times ranged between 35 and 70 p.p.m. SiO_2 equivalents. During hot sunny periods, the ducks remained hidden on shore, and the water cleared to an average of about 8 p.p.m. The average figure for the farm ponds was also about 8 p.p.m., and this degree of turbidity did not prevent filamentous green algae from forming in them.

In spite of the periods of very high turbidity at the hatchery, a heavy growth of *Spirogyra* developed in two of the ponds. Although the algae developed somewhat more rapidly in a pond free of duck activity, this could have been due to other factors. The fact is that the ducks, at a concentration of one bird per 500 square feet of pond surface, did not prevent the development of an undesirable growth of *Spirogyra*.

The two mallards confined on a pond section of 780 square feet did little to control the mat of *Oedogonium* that covered nearly half of the surface in early May. The birds could not swim in the pond without contacting the algal mats, so some of it was destroyed. The adjacent section of pond developed a complete blanket of *Oedogonium* which persisted until late September, while the large masses of algae in the ducks' section remained intact until mid-August. When a portion of the undisturbed mat was stirred with a pole in simulation of duck activity, it recovered fully in a day or so when the algae were in a state of active growth. In September, similar stirring caused the mat to sink to the bottom and remain there until it decomposed. This indicated that control of algal mats from agitation by ducks can be achieved only when the algae are not in a state of active growth.

CONCLUSIONS

The results are rather conclusive in assessing the potentialities of ducks as controllers of algae. Under normal conditions, neither mallards nor domestic ducks make any appreciable reduction in the development of algal growths in farm fishponds. Under conditions of high concentration, mallard ducks may reduce the size of the mat

through agitation or may slow up development by increasing turbidities, but they are unable to control undesirable amounts of filamentous green algal growth. Concentrations of birds having some food preference for algae, such as pintails, might have a greater effect on the algae, but this method of control would probably be impracticable.

LITERATURE CITED

Black, John D. 1946. Nature's own weed killer—the German carp. Wisconsin Cons. Bull. 11(4):3-7.

Gerking, Shelby D. 1948. Destruction of submerged aquatic plants by 2,4-D. Jour. Wild. Mgt. 12(3):221-227.

Herman, Elmer F. and Wendel Anderson. 1947. Control of algal growths in hatchery ponds and raceways. Prog. Fish-Cult. 9(4):211-212.

Smith, William A. 1952. Pond weed control. New York State Conservationist. 6(5):39.

Tiffany, L. H. 1938. Algae, the grass of many waters. Charles C. Thomas, Springfield, Ill.

GENERAL NOTES

A SUCCESSFUL DIVING DUCK TRAP

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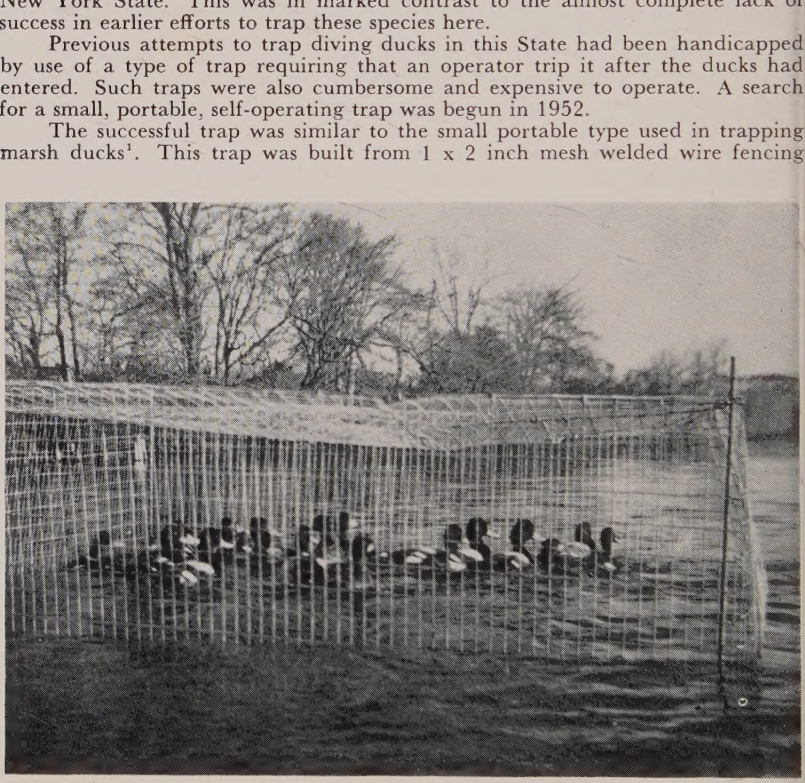
During the winter of 1952-53 over 500 diving ducks were trapped in New York State. This was in marked contrast to the almost complete lack of success in earlier efforts to trap these species here.

Previous attempts to trap diving ducks in this State had been handicapped by use of a type of trap requiring that an operator trip it after the ducks had entered. Such traps were also cumbersome and expensive to operate. A search for a small, portable, self-operating trap was begun in 1952.

The successful trap was similar to the small portable type used in trapping marsh ducks[1]. This trap was built from 1 x 2 inch mesh welded wire fencing



4 feet high. The sides were cut 6 feet long and joined at the corners with hog rings. The top was constructed from the same material as the sides and attached on the front and both sides with hog rings. It was joined to the back panel by threading a stiff wire rod through hog rings attached to either the top or the back only. By removing the rod, the top and the back could be spread apart to allow the operator to remove ducks from the trap with a small fish landing net. An entrance was made by cutting a panel 6 inches wide and 28 inches high in the front of the trap. Nothing was attached to this opening.

[1] Approximately 30,000 marsh ducks have been trapped and branded since 1947 in New York State.

The trap was set up in 2½ to 3 feet of water as close as possible to a diving duck feeding area and baited heavily with corn or wheat. A line of food was run from the entrance of the trap out to where the ducks were working. Depending on the type of trapping site, this line of food might extend anywhere from 75 feet to a quarter of a mile. After the ducks learned to feed in the vicinity, a short line of food (10 to 50 feet) together with a plentiful supply in the trap was found sufficient for successful trapping.

It was found advisable to remove and band the ducks at least twice daily. This was necessary because the trapped ducks dove continually and were soon exhausted if left in the trap for extended periods. Relatively few ducks were able to locate the entrance and escape.

This trap was used successfully on redheads, scaups, and canvasbacks.